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Toward High-Tech Ceramics in 21st Century

Pursuit of New Structural Ceramics

43067063a Tokyo CERAMICS in Japanese Jan 88 p 30

[Article by Y. Yasutomi, Hitachi Laboratories]

[Text] The development of materials has tended to take second place to the development of machinery, but in recent years there has been a growing recognition that innovations in materials themselves will be needed to develop original new products. This is strongly felt to be the key to future materials technology.

But ceramics are still not at all in wide use as an industrial material, although they are now being used more and more for various kinds of elements in machinery. This reluctance to use ceramics is due to their poor cost performance. In analyzing the costs associated with ceramics, it is found that in many cases the cost of the material is less than the cost of cutting, grinding, or otherwise shaping it to the desired dimensions. Most ceramics exhibit a large shrinkage of 15-20 percent when sintered, and the dispersion and deformation thus caused drive up the cost of processing. This is the main reason for the high cost of ceramic components. So if the cost of processing ceramics can be brought down to about the same as for metal products, we are likely to see structural ceramics come into much wider use.

Since joining my company I have been trying in various ways to solve these problems by working on the daunting problem of developing new structural ceramics with superior near net shape in which the dimensional deformation when sintered is small. One approach that could solve these problems is reaction bonding. In this method, as illustrated in Figure 1, a compact formed from metal-silicon powder and silicon carbide powder is reaction-sintered in a nitrogen atmosphere. The metal silicon is caused to react with the nitrogen during sintering while still a raw material, forming silicon nitride. Making use of the expansion of volume that occurs then, the gaps between the particles are filled in, and at the same time the silicon carbide is bonded.

This method keeps the deformation when sintered down to a very low 0.13 percent and has made it possible to develop the world's first silicon

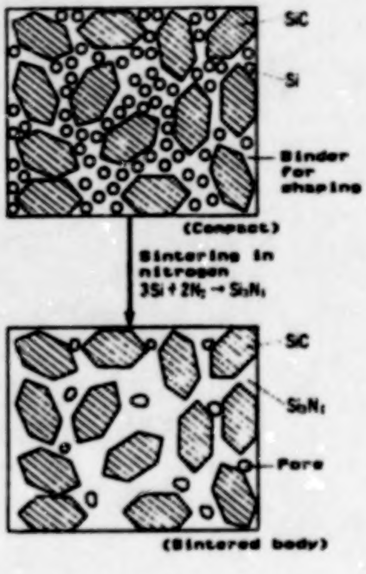

Figure 1. Model Diagram of Si_3N_4-Bonded SiC

nitride-bonded silicon carbide ceramic with bending strength (350 MPa) about as great as that of alumina. Figure 2 [omitted] shows examples of parts made with the material developed.

The material developed, besides showing little deformation when sintered and having great strength, also has good high-temperature strength, resistance to thermal shock, and resistance to oxidation. In addition, the microscopic pores in the material make it easy to grind. These tiny pores can be impregnated with resin or oil in making moving parts with a low coefficient of friction.

I think reaction bonding ceramics present the possibility of creating materials with superior physical properties, depending on the approach. By further analyzing and evaluating the intergranular structure and developing technology for controlling the fine structure, I would like to create ideal reaction bonding ceramics which present many practical advantages and meet the needs of society at low cost. I cannot help hoping that such ceramics will play a part in the objects of our daily life in the 21st century.

Design, Application of Ceramic Composite Particles

43067063a Tokyo CERAMICS in Japanese Jan 88 p 43

[Article by Junichi Hojo, Applied Science Faculty, Department of Engineering, Kyushu University]

[Text] In developing high-function, high-performance ceramic materials, recognition has come to be given to the importance of the design of the particles of the raw material powder and of using designed particles to control the fine structure. With a multi-component material, the uniformity of its composition and the precise control of its composite

structure are key points in achieving the desired functionality. From this viewpoint, the use of composite particles whose composition and structure are controlled will be a revolutionary technology for the future.

Table 1 shows recent examples of the composition of ceramic composite particles, and Figure 1 is a conceptual diagram of the structure and application of composite particles. Composite particles are made by various methods. Particle structure is classified into two broad categories: a uniformly mixed structure, in which different elements are distributed on an atomic or near-atomic level, and a coating structure, in which one of the constituent components covers over the others. The authors have shown that it is possible to synthesize $SiC-Si_3N_4$ composite particles by a gas phase reaction method and control the particle structure by the conditions under which they are synthesized. (Footnote 1) (Hojo, Maeda, Kato, in Yokyo [Ceramics Society], Vol 95, 1987, p 45.) (Footnote 2) (Nakamine, Hojo, Kato, Summary of 24th Conference on Powders, 20, 1986.) The following are examples of applications of composite particles which are presently being studied or are expected in the future.

Table 1. Examples of Synthesis of Ceramic Composite Particles

Method	Composition	Particle structure	Use
Atomization thermal decomposition method	$SiO_2-Al_2O_3$	Uniform mixture type	$SiO_2-Al_2O_3$
Alkoxide method	$SiO_2-Al_2O_3$	Uniform mixture type	Ceramics, mullite
	$TiO_2-Al_2O_3$ $ZrO_2-Al_2O_3$	TiO_2/Al_2O_3 type* ZrO_2/Al_2O_3 type*	Al_2TiO_5 Particle dispersion type composite material
Uniform precipitation method	$Al_2O_3-Cr_2O_3$	$Al_2O_3-Cr_2O_3$ type*	
Gas phase reaction method	$Al_2O_3-TiO_2$	$Al_2O_3-TiO_2$ type*	Al_2TiO_5
	$Al_2O_3-ZrO_2$ $SiC-Si_3N_4$	$Al_2O_3-ZrO_2$ type* Uniform mixture type SiC/Si_3N_4 type* Si_3N_4/SiC	Particle dispersion type composite material

*Coating type: coating phase/particle interior phase

(1) Synthesis of composite oxides: There are many examples of such synthesis, including mullite and spinel. High-performance superconductors may be made practical by greater uniformity in the composition on the Ba-Y-Cu composite oxides which are now receiving much attention as high-temperature superconductors.

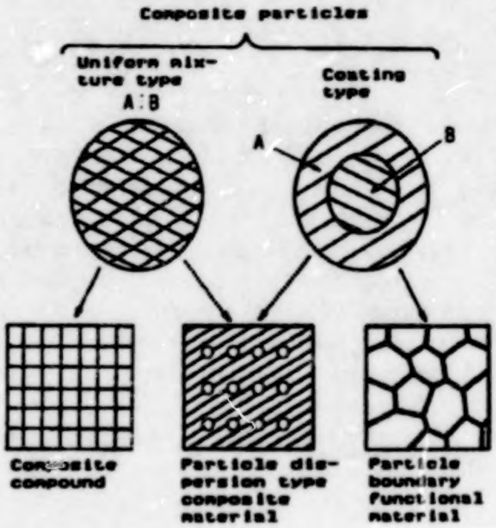

Figure 1. Structure and Applications of Composite Particles

(2) Manufacture of ceramic composite materials: Al_2O_3-ZrO_2 materials, which are very tough, and SiC-Si_3N_4 materials, which are strong and highly resistant to thermal shock, are being given much attention. It is possible to achieve phase separation of uniform mixed particles or, by using coating particles, to achieve high dispersion and uniform distribution of second-phase particles in the matrix. In the future, various kinds of composite materials may appear, using SiC, Si_3N_4, AlN, BN, Al_2O_3, ZrO_2, and other compounds.

(3) Uniform adding of auxiliary substances to sintering raw materials: Segregation of auxiliary substances to the grain boundary of sintered bodies lowers the strength. If composite particles coated with an auxiliary substance are used as the sintering raw material, a small amount of auxiliary substance can have great effect, producing a high-density, high-strength sintered body. Such improvements in sintering methods hold forth the promise of practical high-temperature mechanical materials using SiC or Si_3N_4.

(4) Design of particle boundary functional electronic materials: ZnO varistors and $BaTiO_3$ PTC thermistors consisting of a low-resistance grain boundary layer and a high-resistance particle interior are being made practical. It may be possible to improve the physical properties or discover new functions by actively forming the grain boundary layer using coating particles.

As seen above, the use of composite particles could make it possible to design various kinds of ceramic materials, and future research looks promising.

13278/9365

SUPER HEAT-RESISTANT TURBOCHARGER DEVELOPED

43066512 Tokyo JIDOSHA GIJUTSU in Japanese Oct 87 pp 1150-1155

[Article by Masashi Yoritaka and Yukio Yamamoto, Technical R&D Institute, Mazda Motor Corp.; Yasuaki Hasegawa, Yokohama branch of Technical R&D Institute of Mazda Motor Corp.; and Tomio Hokari, Development Division of Sawa Factory, Hitachi Ltd.]

[Text] 1. Foreword

The turbochargers presently favored by most motor companies use inconel 713C (Ni-radical-Cr-Al-Mo series super alloy) for the turbine blade. Inconel 713C is suited for mass production because it is comparatively cheap and good for casting; it is also easy to supply from melting stock. The exhaust gas temperature has had a tendency to rise in recent years because automobile makers are trying to achieve high automobile performance and good fuel consumption. Exhaust gas temperature of the racing engine is very high. At the same time, the creep strength of the turbine blade at high temperatures whose number of revolution reaches more than a hundred thousand a minute will become a problem because the blade undergoes large centrifugal force. The creep strength of inconel 713C is not always sufficient, a factor that is posing a problem in the turbocharger engineering. We have tried using a new Ni-radical super alloy in place of inconel 713C. In addition, heat resistance of the turbine casing is also an important question. Generally, high Si ductile iron or Ni resist ductile iron are used, but we tried to use Co-radical super alloy whose heat resistance was remarkably improved.

2. Necessity of Super Heat-Resistant Turbocharger

Generally speaking, bringing the fuel mixing ratio close to the theoretical air-fuel ratio is an effective means of making the output of turboengine and the fuel consumption compatible. However, since the exhaust gas temperature becomes very high in the high revolution area and the heat resistance of the turbocharger is a problem in the engine exhaust system, the fuel so far has been a rich mix. Figure 1 shows a model relation between the output, fuel consumption, exhaust gas temperature, and the air-fuel ratio in the high revolution area. The operation in the hatching zone is limited by past T/C specification, and the operation in a thinner mixing ratio region is

necessary to further improve the output (Pe) and the fuel consumption (be). An ideal one is in the middle of pe-Max and be-Min. For this purpose, a rise in the exhaust gas temperature cannot be avoided, and the development of excellent heat-resistant turbochargers has become indispensable.

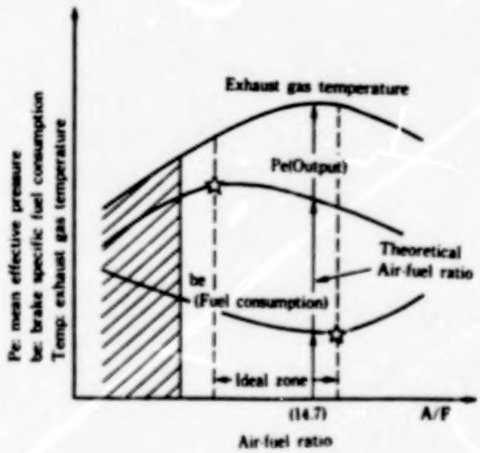

Figure 1. Model for Output, Fuel Consumption, Exhaust Gas Temperature

3. Controversial Points of Turbocharger of Past Specification

The basic specification of the turbocharger of this research is twin use HT-20 model (Hitachi, Ltd.) A/R = 0.9 in (22.86 mm) turbine maximum diameter 66 mm.

Figure 2 [not reproduced] shows the sketch of the turbocharger and the terminology.

The past specification used inconel 713C for the turbine blade and Ni resist D_2 for the turbine casing. When the turbocharger of this specification was used in a rotary engine for racing, its heat-resistance reliability was insufficient, and it developed problems in a short time. The problems were the breakdown of the turbine blade due to the insufficient high-temperature creep strength, and the thermal deformation, cracks, formation of oxide film, etc. of the turbine casing caused by the insufficient high-temperature creep strength and the resistance to oxidation.

4. Application of New Material and Preparatory Test

4.1. Selection of Turbine Blade Material

Turbine blade materials were selected aimed at the high-temperature creep strength. Instead of the past inconel 713C, Ni-radical alloy TRW-6A[1,2], MAR-M247[3,4], and TM-321[3,4] were selected. TRW-6A and MAR-M247 were developed in the United States, and TM-321 was developed in Japan. Table 1 and Figure 3 show the chemical composition and the creep strength of each alloy.

Table 1. Chemical Composition of Turbine Blade Material

(Wt%)

	Ni	Cr	Co	Mo	W	Ta	Nb	Al	Ti	C	B	Zr	Other
713C	Bal.	12.5	-	4.2	-	-	2.0	6.1	0.8	0.12	0.012	0.10	
TRW6A	Bal.	6.1	7.5	2.0	5.8	9.0	0.5	5.4	1.0	0.13	0.02	0.13	0.5Re 0.4Hf
MAR. M 247	Bal.	8.2	10.0	0.6	10.0	3.0	-	5.5	1.0	0.07	0.02	0.09	1.5Hf
TM 321	Bal.	8.1	8.2	-	12.6	4.7	-	5.0	0.8	0.11	0.01	0.05	0.9Hf

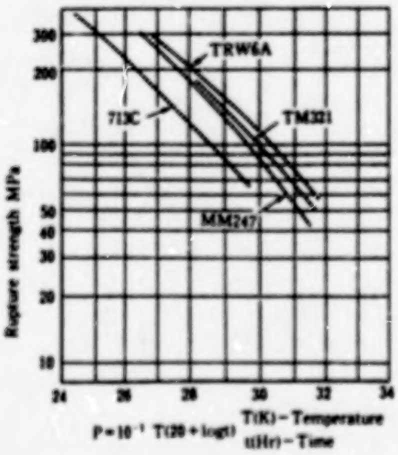

Figure 3. Turbine Blade Material Creep Strength

TRW-6A is strongest in the creep strength, followed by TM-321 and MAR-M247. The creep strength of all these materials is superior to that of the past material inconel 713.

4.2. Selection of Turbine Casing Material

Co-radical super alloy FSX 414(2) was selected as the material for the turbine casing for the past Ni resist D_2. Table 2(5) shows its chemical component, and Figure 4 shows its creep strength. They also indicate the data of Ni resist D_5S for reference.

Table 2. Chemical Composition of Turbine Casing Material

(Wt %)

	Ni	Cr	Co	W	Ta	Al	Ti	C	B	Fe
FSX 414	10.0	29.0	Bal.	7.5	-	-	-	0.25	0.01	1.0
	Fe	T.C	Si	Mn	Ni	Cr	P			
Niresist D2	Bal.	2.5	2.0	1.0	20.0	2.3	0.05			
Niresist D5S	Bal.	2.0	5.5	0.5	35.0	2.5	0.05			

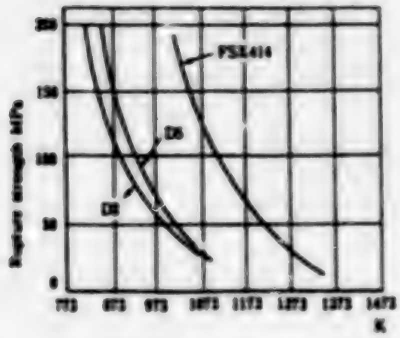

Figure 4. Turbine Casing Material Creep Strength (1000 Hr)

The reason Co-radical super alloy was selected for the turbine casing was that it has an excellent creep strength. That atmospheric casting is possible in its manufacture was also a big factor in the selection.

4.3. Basic Materials

It is necessary to know the oxidation resistance, castability, etc. as well as the high-temperature creep strength of the material to select the most suitable material.

Figure 5 shows the results of the oxidation test of the materials for the turbine blade.

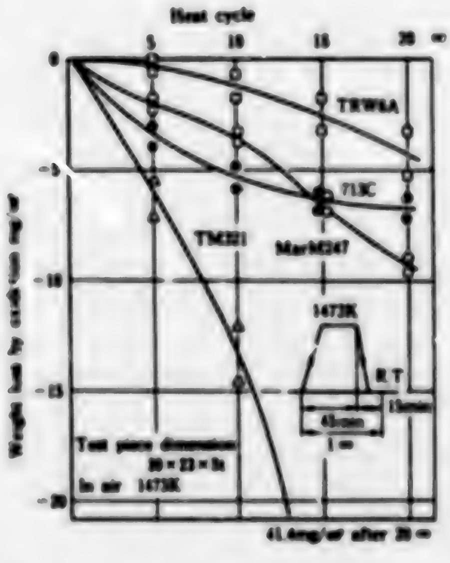

Figure 5. Turbine Blade Material Oxidation Resistance

The test result of TRW-6A is better than that of inconel 713C, and that of TRW-6A and MAR-M247 was almost the same as that of inconel 713C. TM-321 has a poor oxidation resistance. It was confirmed that the aluminum pack

cementation(6) was effective to improve the oxidation resistance, and at the same time, some corrosion resistance tests were also conducted, but the results are omitted here. On the other hand, as shown in Figure 6, FSX 414 is very good compared to Ni resist D_2 as the material of the turbine casing.

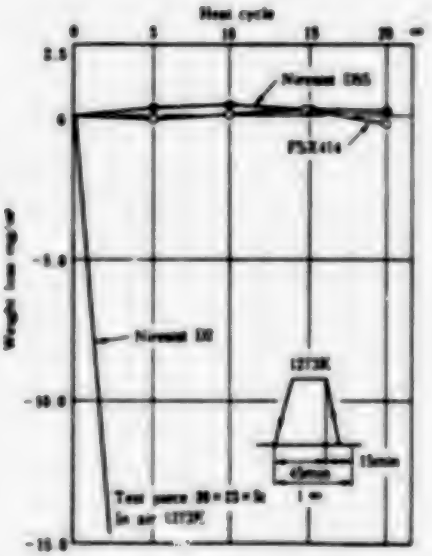

Figure 6. Oxidation-Proof Property

The turbine blade was vacuum cast by the lost-wax method, and the turbine casing was manufactured by the atmospheric casting. TRW-6A has a poor castability (many cracks occurred) and it had to be given up. MAR-M247 and TM-321 were on the level of practical use.

On the other hand, FSX 414 had no problem of castability as a material for the turbine casing.

5. Manufacture of Turbocharger Unit Evaluation System

A unit evaluation system (Burner-rig tester) was manufactured to quantitatively evaluate the heat-resistance reliability of the turbocharger test manufactured by the new material concept.

Figure 7 shows the schematic diagram of the evaluation system. [Figure 8 not reproduced]

The fuel of this system is propane gas, and it can simulate the exhaust gas of various engines. It can be freely set within the scope of the combustion gas temperature 1073-1473K and the combustion gas pressure 0.02-0.14 Pa.

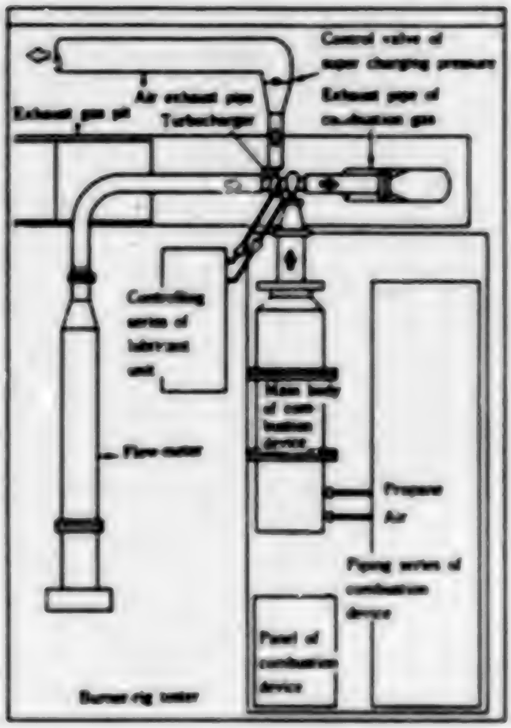

Figure 7. Evaluation System

6. Evaluation of Super Heat-Resistance Turbocharger

The evaluation by the burner-rig tester on the trial production that used FSX 414 for the turbine casing and MAR-M247 and TM-321 for the turbine blade was conducted from preparatory tests and other data. The same evaluation was conducted on the inconel 713C for comparison.

6.1. Rupture Life Turbine Blade

Figure 9 shows the relation between the operation time for the creep rupture of the tip of the turbine blade and the combustion gas temperature arranged by the (Ralson) mirror parameter and the number of revolutions of the turbine (indicates stress).

The rupture life of the turbine blade using MAR-M247 and TM-321 is longer than that of inconel 713C, and its durability is more than 1373K 50Hr at the practical number of revolutions (110,000-130,000 rpm). No significant difference was recognized between MAR-M247 and TM-321. Furthermore, it is presumed that the reason no significant difference was recognized even though TM-321 indicated a superior creep strength in Figure 3 is that it is set off by the excessive centrifugal force when the specific gravity of TM-321 is applied to the body of revolution.

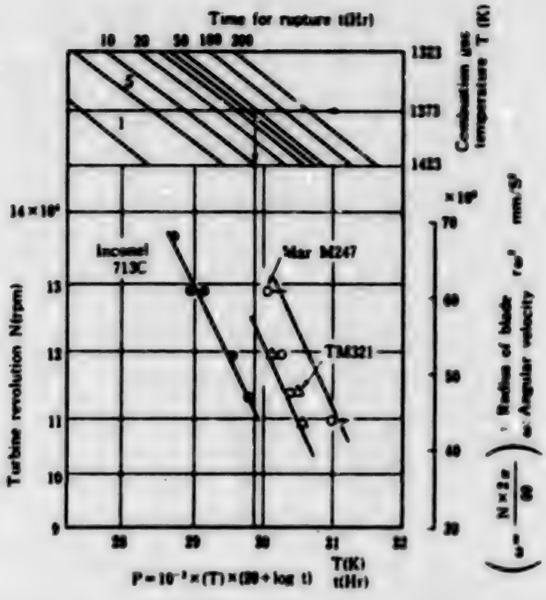

Figure 9. Rupture Life of Turbine Blade

6.2. Structure Change of Super Alloy

If the turbine blade structure before and after the test is observed, the coarsening of the r' phase was observed. If the r' phase becomes coarse, the high-temperature strength is remarkably lowered; therefore, the high-temperature stability of the r' phase is important. Then, the test pieces were cut from the turbine blade that were heat maintained in the atmosphere; the course of the r' phase change was observed, and a comparison of materials was conducted.

In the three super alloys, inconel 713C showed quickest r' phase coarsening, beginning after 3 hours.

Coarsening of the r' phase of the MAR-M247 and TM-321 can be confirmed after 24-hour heating, and the phenomenon only partially occurred.

From the above, it can be understood that the r' phases of MAR-M247 and TM-321 are very stabilized compared to that of inconel 713C. This result explains the great difference in the rupture life of the turbine blade indicated in Figure 9. [Figure 10 not reproduced]

7. Rupture Mechanism of Turbine Blade

7.1. Rupture Process

Checks were conducted every several hours continuing a regular operation of 11 x 10^4 rpm and 1423-1443K to make clear the rupture process of the turbine blade. Figure 11 shows the result of the measurement of the elongation of the turbine blade in the direction of radial using MAR-M247 and TM-321.

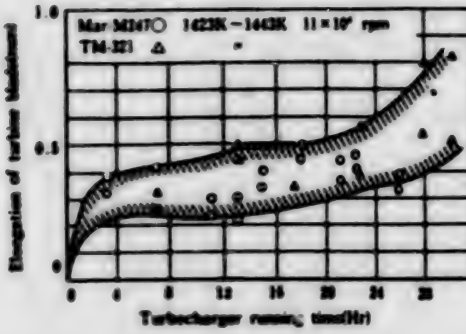

Figure 11. Elongation in Tip of Blade

It was found that both entered the stabilized period after showing a sudden elongation in the initial stage; they showed a sudden elongation again in the stabilized stage. This trend is similar to the pattern of the general creep deformation. Furthermore, the elongation of 0.4-0.8 mm was eventually recognized by our measurement, but there are considerable differences in the elongation between the turbine blades in both stages. It is believed that this is not mere dispersion, but a difference in the cast structure. [Figure 12 not reproduced]

Figure 13 shows the rupture process of the turbine blade.

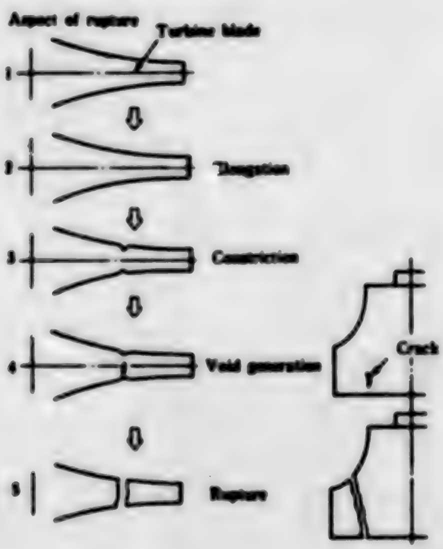

Figure 13. Rupture Mechanism of Turbine Blade

First, the turbine blade elongates a little. This elongation gradually increases, and constriction is produced about 10 mm from the tip. Then, a hole is formed inside the constriction by the creep deformation. This hole becomes larger with the progress of the deformation; it reaches the surface and in the end becomes a crack. Eventually it bursts by the contact of the

turbine blade and the turbine casing. Further, the place this constriction is produced is a position where the stress is high and the temperature is severe.

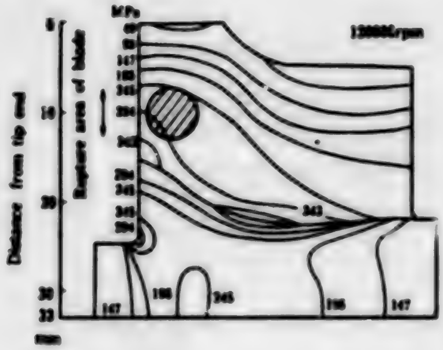

Figure 14. Stress Distribution of Turbine Blade

7.2. Influence of Cast Structure

Creep is the main factor of the cause of the rupture of the turbine blade, but there are differences among the blade tips of the same turbine as indicated in Figure 11. This is because the structure of each blade is different. Figure 15 [not reproduced] shows pictures of the cast structure of two blades.

These two pictures show the constriction by the creep in the middle of the blade. The upper picture shows no cracks, but the lower picture already shows many cracks produced in the grain boundary in the middle part. This indicates that the grain boundary has a great influence on the rupture life of the blade.

8. Consideration

Although the manufacture this time was a normal casting, not a controlled one, a one-direction cast structure was observed in many turbine blades. Figure 16 [not reproduced] shows a one-direction cast structure. The reason such cast structures were obtained is that the compositions of MAR-M247 and TM-321 are easily cast in one direction[7]; the shape of the turbine blade is gradually changed from the thin tip part to the thick middle part.

However, it is necessary to have some kind of positive structure control to obtain the perfect one-direction cast structure for all blades.

9. Conclusion

Finally, Ni-radical superalloy MAR-M247 was adopted for the turbine blade and Co-radical superalloy FSX 414 was adopted for the turbine casing including the supply of the melting stock. The process confirmed remarkable improvement in the heat resistance of the turbocharger was possible by

completing the burner-rig tester to evaluate heat resistance in extreme conditions and considering the basic properties of various heat-resistant materials. The following information was obtained.

(1) The rupture life of the turbine blade is closely connected with the high-temperature stability of the r' phase of super alloy.

(2) The rupture mechanism first begins with the elongation of the turbine blade, develops to the crack on the surface from the formation of the creep void inside, then the rupture is produced.

(3) There are differences in the cast structure even among the blades of the same material, and the breakdown begins from the grain boundary inside. It is a strong blade whose structure comes close to the one-direction coagulant structure without the sideway grain boundary.

FOOTNOTES

1. Rempei Yoda: Development and Present Situation of Super Heat-Resistant Material, 1982, 7, 10.

2. NICKEL BASE ALLOYS INCO.

3. M. Yamazaki: 1983, Tokyo International Gas Turbine Congress, Nickel-Base Super Alloys Developed for Advanced Gas Turbine in Moon Light National Project.

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5. NI-RESISTS AND DUCTILE NI-RESISTS INCO.

6. SIMS-HAGEL THE SUPER ALLOYS WILLEY.

7. Michio Yamazaki, et al.: Moonlight Project, R&D of Heat-Resistant Alloy in the R&D of High-Efficiency Gas Turbine--Final Result Report. Mar 1985. National Research Institute for Metals, Science and Technology Agency.

20155/6091

Power Companies Cooperation in R&D Projects Discussed

43062527 Tokyo ENERUGI FORAMU in Japanese Oct 87 pp 102-103

[Article: "Commissioned/Joint Research Projects Are Now Active Among Power Companies"]

[Excerpt] Following the economic currents of the times--such as the shift from high to low economic growth, the change in the industrial structure from heavy, thick, long, and big to light, thin, short, and small, and the intensification of industrial competition--various industrial circles are earnestly developing new technologies utilizing the operational resources they have cultivated. The investment of power companies in R&D over the past several years has shown a remarkable increase. The combined R&D expenses of the nine power companies, the Electric Power Development Co., the Japan Atomic Power Co., and the Central Research Institute of the Electric Power Industry for FY 1987 totals about ¥167 billion, which represents an increase of about ¥38 billion over the previous year. (Investigated by the Central Power Industry Association).

While the role of the electric enterprise is becoming increasingly important, the positioning of technical development in power management has also changed. At present, the greatest importance is placed on establishing the technical base. Concurrently, the fields of research are expanding year by year in order to meet the increasingly diversified needs of consumers.

Technical development to enhance the operational efficiency of equipment and to reduce costs has become the focus of technical development in this period of stabilization. This differs from the pattern during the high economic growth period when equipment was energetically reinforced. The power industry is losing its attractiveness to manufacturers, and it is true that it has become necessary for the power industry to conduct research that sometimes encroaches into the realm of manufacturing technologies. At the same time, the forward-looking attitude of the power industry in trying to conduct basic research is also growing stronger. For these reasons, the R&D expenditures of the power industry have experienced a remarkable increase recently.

Concurrent with the growth of total R&D expenditures and in the number of R&D projects, it should also be noted that the number of projects undertaken in cooperation with organizations outside the power companies--that is, commissioned or joint R&D projects--is increasing. Commissioned R&D projects can be either fully or partially commissioned. Joint R&D projects can be undertaken with other companies, universities, or government agencies.

Many of the common research subjects of the past, such as improving technology to enhance supply reliability or to reduce costs, have been conducted by the Central Research Institute of the Electric Power Industry, individual power companies, or by the nine power companies together. Such research fields are often at the frontiers of technology, and for this reason there is a trend toward joint R&D with universities or manufacturers in many areas in which basic research elements are strong. It is also the same for large-scale R&D, such as atomic-related technology, and joint R&D projects that cross national boundaries have become much more important in this field.

The attached table shows the principal commissioned or joint R&D projects of each power company. The number of commissioned or joint R&D projects of the power companies is increasing every year, and the same power companies are conducting over 400 commissioned or joint R&D in a year.

A novel trend is that the number of joint research projects of each power company is increasing in such fields as the utilization of superconductivity technology, which has been highlighted of late, and communication/information-related technology where the power industry is directing its efforts toward automation, making daily business more efficient, and also to create new businesses. The number of commissioned or joint R&D projects aimed at the application of artificial intelligence technology to the energy system has also been increasing. The number of organizations and enterprises with which commissioned or joint R&D projects are conducted is also gradually increasing as the research subjects are becoming more diversified.

The power companies have been conducting enthusiastic research efforts in the development of appliance systems aimed at creating an all-electric home. They have been working with domestic electric appliance makers who are sensitive to the general contractor and who understand consumer needs. Their goal is to offer new products at the most reasonable prices and to meet the needs of consumers.

The content of R&D projects is hard to determine because of a high degree of corporate secrecy, but it is believed that cooperation with other industries, universities, and government agencies will become much stronger in the future. The number of instances of technical cooperation and information exchanges without formal contracts such as joint research is also increasing regardless of developments inside and outside the country. It might be said that in the future it would be useful to study whether or not the power companies utilize the results of their commissioned or joint

R&D projects only for themselves or if they utilize the technology to develop new products.

Principal Commissioned or Joint Research Projects of Power Companies (FY 1987) (Note: Includes ongoing projects)

Name of company	Main research subjects	Research organization	Outline of research
Hokkaido Electric Power Co., Ltd.	Deicing and de-snowing of transmission lines	Hokkaido University (Professor Goro Wakahama)	Analysis of iced or snowed samples and analysis of meteorological phenomenon to prevent icing and snowing accidents
	R&D of heatpump utilizing terrestrial heat	Hokkaido University (Professor Sumi Ochifuji)	Development of heatpump suited to cold districts
	R&D of regenerative heater	Hokkaido Prefectural Industrial Laboratory	Development of inexpensive and high-performance regenerative
	Research into the effect of property change of coal ash on character of mixed slurry material	Civil Engineering Laboratory of Hokkaido Development Bureau	On new ash produced at Toma-higashi-atsuma Power Plant
Tohoku Electric Power Co., Ltd.	Research into application of semiconductor device	Tokyo University and others (Professor Fumio Harashima)	Test manufacture high frequency PWM using electrostatic inductive semiconductor and conduct characteristic confirmation test
	Demonstration test of fuel cell	Tohoku University (Professor Takeshi Anayama), Fuji Electric Co., Ltd.	Demonstration test of phosphoric acid-type fuel cell (50 kw class) plant characteristic test, etc. and FS of practical model. Power distribution linkage test is also conducted

[continued]

[Continuation of Principal Commissioned or Joint Research Projects of Power Companies]

Name of company	Main research subjects	Research organization	Outline of research
	Research into snow-melting and snow-utilization	Niigata University (Professor Shunichi Kobayashi)	Demonstration and improvement tests of snow removing technology by robot snow removing device, wiper type snow removing device, etc.
	Investigation of character of winter thunder on Japan Sea side by new thunder detector	Tokyo University (Professor Tatsuo Kawamura, Assistant Professor Masaru Ishii)	Observe winter thunder and improve accuracy of lightning forecast system that can be used in lightning forecasting
Tokyo Electric Power Co., Ltd.	New lightning detector	Toshiba Corp., Hitachi, Ltd., Mitsubishi Electric Corp.	
	Long-range, curved-line excavation robot	Kanto Denki Koji, Co., Ltd.	
	Customer service service	KEC, Sumitomo Electric Industries, Ltd.	
	Equipment for fully automatic system	Toshiba Corp., Meidensha Electric Manufacturing Co., Ltd.	
	Radar probing for buried objects	Mitsubishi Electric Corp.	
	Research study of thunder phenomenon	Tokyo University (Professor Kawamura)	
	Higher harmonic tidal current calculation program	Meiji University (Professor Tsuzuki)	
	Research into air conditioning system utilizing low-temperature cold water	Tokai University (Professor Tanaka)	

[continued]

[Continuation of Principal Commissioned or Joint Research Projects of Power Companies]

Name of company	Main research subjects	Research organization	Outline of research
	Ground research on deformation characteristics	Tokyo Institute of Technology (Professor Yoshimi)	
	Observation of lightning phenomenon	Utsunomiya University (Professor Kawamata)	
Chubu Electric Power Co., Ltd.	Automatic water analyzer for thermal power plant	Electro Chemical Instruments Co., Ltd., Horiba Manufacturing Co., Ltd.	For efficient control of boiler water quality, develop continuous measurement instrument whose accuracy is equivalent to that of manual analysis; tests are conducted on its practical use
	Making fine ceramics for gypsum slurry pump	NBK Insulators, Ltd.	To make long-life pump impeller, research on application of fine ceramics to impeller is conducted
	Instantaneous voltage drop compensation device	Nisshin Electric Co., Ltd.	Develop cheap and compact device to compensate instantaneous voltage drop for about 0.1 second by continuous time and several 10 percent by dropping range
	Divided conduit to make conduit porous	Sumitomo Electric Industries, Ltd., Fujikura Cable Works, Ltd.	Develop divided conduit to make effective use of communication cable conduit, and conduct test for practical use

[continued]

[Continuation of Principal Commissioned or Joint Research Projects of Power Companies]

Name of company	Main research subjects	Research organization	Outline of research
	Research on technology for removing unburnt carbon from	Ishikawajima-Harima Heavy Industries, Co., Ltd.	Establish technology to remove unburnt carbon from ash obstructing intensity and color tone
Hokuriku Electric Power Co., Ltd.	Research in forecast of winter thunder	Japan Meteorological Association (Toyama Branch)	
	Research in utilization of coal ash as a construction material	Kanazawa University	Research in utilization of coal ash as soil stabilizer, road bed material, fine aggregate for concrete, and mixing material
	Research in utilization of heat pipe to cool rotating machine bearings	Fujikura Cable Works, Ltd.	
	Research on critical temperature and grating constant of oxide superconductor	Toyama University (Professor Katsunori Mori)	
	FAX transmission system by portable radio	Toyo Communication Equipment Co., Ltd.	
Kansai Electric Power Co., Inc.	Remote control system for switches	Four makers	
	Research in high-efficiency combined cycle generation	Two makers	
	Liquid ice regenerating air-conditioning system	One maker	

[continued]

[Continuation of Principal Commissioned or Joint Research Projects of Power Companies]

Name of company	Main research subjects	Research organization	Outline of research
	Large-capacity household electric appliances	Two makers	
	Research in superconductive generator quick response excitation	Kyoto University	
	Research in high-temperature superconductive material	Kyoto University	
	Research in strength evaluation and improving ceramic joining methods	Osaka University	
	Investigation of closed cycle MHD generation	Tokyo University of Technology	
Chugoku Electric Power Co., Inc.	Model trial of knowledge information processing (AI)	Hiroshima University	System design of AI system development, study on programming work, and CAI system model development and trial
	Integrated automatic power distribution system	Toshiba Corp., (Nihon Asutekku), (Pasuko), others	Manufacture software for operation, function, and demonstration tests, and for additional functions
	Research on measures to prevent instantaneous voltage drop during transmission line problems	Hiroshima University	Theoretical analysis of instantaneous voltage drop prevention method, and test manufacture and experiment of countermeasure device

[continued]

[Continuation of Principal Commissioned or Joint Research Projects of Power Companies]

Name of company	Main research subjects	Research organization	Outline of research
	Research in transformer rush phenomenon by numerical analysis of magnetic field	Okayama University	Numerically analyze excitation rush phenomenon electromagnetically, and elucidate its mechanism
	Research on transformer equipment monitoring device	Mitsubishi Electric Corp.	Develop and introduce transformer equipment monitoring system, and conduct demonstration test
Shikoku Electric Power Co., Inc.	Although it has no projects conducted under commissioned or joint R&D contracts, the company directs its efforts to improve its technology by receiving technical guidance from universities, etc. specializing in the fields as required.		
Kyushu Electric Power Co., Inc.	R&D of automatic meter reading system	Toshiba Corp., Sumitomo Electric Industries, Ltd., Kyushu Electric Manufacturing Co., Ltd.	Verification test of automatic meter reading system using applied signal technology such as distribution or communication line carrier, and optical fiber in real scale
	Research on home air-conditioning and hot water supply system	Technical Laboratory of Taisei Construction Co., Ltd.	Conduct demonstration test of electrified system combined natural energy and electric energy establishing model houses
	Research in application of superconductive energy storage system to power system	Kyushu University, Kinki University	Conduct quantitative evaluation of application of superconductive technology to power system

[continued]

[Continuation of Principal Commissioned or Joint Research Projects of Power Companies]

Name of company	Main research subjects	Research organization	Outline of research
	Investigation and practical development of electric automobile	Mitsubishi General Research Institute	Confirm running performance, battery performance, and economy in actual operation. Study by comparing domestic and foreign electric cars
	R&D of robot to diagnose inside of boiler tube	Development Laboratory of Tsuchiura Factory of Hitachi Construction Machinery Co., Ltd.	Conduct development of flaw detection robots to investigate damage in pipes by ultrasonic and optical sensors
Central Research Institute of Electric Power Industry	Used fuel storage technology	American Electric Power Research Institute	Conduct safety demonstration test on cask storage
	Performance evaluation of alternating current superconductive line	Nihon University, Yokohama National University	Grasp basic characteristic of alternating current superconductive coil and examine possibility of its application to superconductive transformer, etc.
Electric Power Development Co.	Demonstration test of fluidized bed incineration boiler	Coal Technology Laboratory (foundation)	Demonstration test of fluidized bed incineration boiler (50 MW scale) that can simplify smoke disposal equipment and can make boiler smaller because many kinds of coal can be used

[continued]

[Continuation of Principal Commissioned or Joint Research Projects of Power Companies]

Name of company	Main research subjects	Research organization	Outline of research
	Development of automatic furnace temperature measuring technology	Toyohashi Science and Technology College	Develop technology to measure temperature distribution and the movement of soiled material in boiler; try to stabilize boiler operation
	Research study on applicability of coal ash to road construction material	Public Works Research Institute of Ministry of Construction	Follow-up survey test of coal ash used on ground; on-site test of ash-earth mixed ground; and basic material test of conventional ash

20155/9365

MHD GENERATING TECHNOLOGY, NEW MATERIALS

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[Article by Takayasu Okuo, chief researcher of the Energy Conversion Research Laboratory, Energy System Department, Electronic Technology General Research Institute: "MHD Generating Technology and New Materials"]

[Excerpt] Preface

The aim of the MHD Power Generating R&D Project, which is part of the Moonlight Program is to achieve a total power generating efficiency of 50 percent or more by developing magnetohydrodynamic (MHD) steam power complex power generating system for base loads, via fuel oil combustion. The 1st-phase project (1966-1975) and the 2nd-phase project (1976-1983) have already been implemented. These projects have resulted in many of the technical achievements necessary for practical use of an MHD power generating system, including the development of system components. After completion of the 2nd-phase project, basic research concerning the coal-fired power generating channel, combustors and heat exchangers is being conducted as a joint research venture within the laboratory.

This paper introduces the structure of the insulating walls for MHD power generating channel and the results of material research.

1. MHD power generating system and background of development

It is estimated that, among fossil fuel resources, liquid fossil fuel will be most quickly exhausted because of excess consumption. As everybody knows, regulation of the oil supply by the oil-producing countries and oil price increased due to the oil shock have had great effects on the world economy. This, however, gave an impetus to the practical use of new energy generation and conversion systems, together with the utilization and development of natural energies. Additionally, natural gas and coal are being reviewed as replacements for liquid fossil fuel. Total coal reserves are estimated at 11 trillion tons, which is the largest energy resource possessed by mankind. It is an urgent task, therefore, to study methods of effectively utilizing coal.

As the above shows, coal will play a major role as a fuel for MHD power generating plants for base loads and it appears that a coal-fired system will

be employed for the retrofitting-type MHD power generating system. The latter is designed to increase power generating capacity and efficiency by connecting an MHD generator to the topper of conventional thermal power plants.

Technical developments being carried out by the United States, the Soviet Union and other major countries are aimed at:

--Construction of large-capacity power plants and reduction of power generating costs by enhancing power generating efficiencies.

--Substantial reduction of pollution in the atmosphere and rivers by decreasing the release of NOx, SOx and warm drainage materials.

In Japan, coal-based thermal power generation is considered to be a base power supply that in the future will supplement nuclear power generation, which is looked on as the long-term primary energy supply. It is estimated, therefore, that coal-based gasified complex power generation and coal-based thermal power generation will rapidly increase in the future. Thus, it can be said that the construction of coal-fired power generating plants for large-capacity open cycle base loads is the practical target for the MHD power generating system and that a great deal of efforts is being exerted in researching and developing such power generating plants.

As a specific example of the practical application of open-cycle MHD power generation, short-time high-power output MHD generators can be cited. They have already been put to practical use as a power supply for earth crust surveys. They are superior to other generators in starting performance and portability and can generate power for about 10 seconds. Furthermore, such pulse output is being studied for use in nuclear fission as a special power source. Meanwhile, a closed-cycle MHD power generating system using inert gases is thought to be promising as medium-capacity power generating plant for urban use. Research and development of such a system is under way, but has only reached the stage where the possibility of power generation by short-time operation has been verified. It is necessary, therefore, to make clear, in the future, whether or not it will be possible to achieve long-time continuous power generation and sufficient durability of system components. In addition, basic research on a liquid metal closed-cycle MHD power generator to be used as a space power supply, etc., is proceeding.

2. Current Development Status of Power Generating Channel

The MHD power generating channel is a system component (for MHD power generation) that has been studied intensively. The details of its materials and design techniques, as well as its behavior and specific features, are fully known to us. The Linear Faraday-type and the diagonal-type power generating channels are being widely used and the former's durability is being investigated most positively. A power generating passage of the linear Faraday-type channel is composed of insulating walls and electrode walls, in which electrodes and interelectrode insulators are arranged alternately.

High-temperature and high-speed combustion gas, to which a small quantity of potassium is added, is fed in to the power generating passage. Then, a strong magnetic field is formed using a superconducting electromagnet to effect MHD power generation. In the case of low-temperature metal power generating channels (for the coal-fired power generating system) widely used in many power plants, slags having a thickness of about 2 mm adhere to insulating wall surfaces and electrode wall surfaces. These surfaces become transformed into a liquid phase and begin to float. The slag layers reduce the head loss and internal impedance of the power generating channel, with satisfactory effects on the durability of insulating walls. In the slag layers on the electrode walls, however, O_2, K, SO_2 ions, etc., separate out and collect on electrode interfaces due to the action of the electric field. On the cathode wall, therefore, a short circuit takes place between adjacent electrodes due to the accumulation of K ions, thereby reducing the life of the electrodes. On the anode wall, the segregation of O_2 ions accelerates the generation of arcs. In addition, SO_3 ions promote erosion of the electrodes. Thus, the slagging environment in the coal-fired system produces factors that greatly deteriorate the durability of the insulating walls. This creates many more difficulties in developing the coal-fired system, as compared to the oil-fired system.

With respect to the technological level associated with the power generating efficiency of the MHD power generating channel actually attained, the enthalpy extraction efficiency is 11 percent (7.5 sec) in the HPDE (United States) and 5 percent (continuous) in the U-25 (USSR). In other words, the power generating efficiency of the MHD power generating channel has only achieved about 50 percent of the target for practical use (20 to 25 percent). The enthalpy extraction efficiency, however, depends greatly on the size of the power generating channels. Thus it is expected that the construction of a large-scale power generating channel will enhance enthalpy extraction efficiency. It will be necessary, in the future, to assess power generating efficiency and durability using a demonstration plant.

On the basis of repeated operations (over 1300 hours) conducted by AVCO in the United States under mock coal-fired power generating conditions, it is estimated that a power generating channel with a durability of over 8,000 hours can be achieved by the extrapolation of electrode consumption. In this experiment, however, the durability of the insulating walls was not assessed; the emphasis, rather was laid on the durability of the anode electrode materials (platinum and stainless steel). Under the power generating conditions created by the use of low-temperature electrodes, interelectrode insulators and side walls in the vicinity of the electrodes cannot avoid the effects of current phenomena due to current lead and dielectric breakdown. In the long-duration (430 hours) experiments (conducted in the 2nd-phase plan performed with the ETL Mark 7 unit using mock fuel oil (kerosine + SO_2), exfoliation of the alumina layer of the cathode insulating wall (water-cooled copper base alumina thermally sprayed type) was observed. Mock power generating channel have revealed that this phenomenon occurs more severely under the slagging conditions arising from the use of the COM-fired system. Thus, the improvement and development of insulating walls is an important R&D subject, as is the development of long-life electrodes.

Table 1. Evaluation of Insulating Ceramics

Application	No.	Ceramics	Evaluation OIL[5]	Evaluation COM[5]	Note
	1	Al_2O_3 Coating[2]	E	P	1) Plate insert type
Cold Type	2	BeO[3]	E	E	2) 03mm' coating on
Insulator	3	SiC.1BeO(SC101)[3]	E	E	water cooled
					copper substrate
Semi-hot type	4	MgO(MG.S[3])	G	P	3) Ceramic-metal
Insulator	5	Al_2O^3.AIN.SIN_3N_4[4]	G	G	bonding type
					with complaints
	6	Al_2O_3 (SSA.S)	G	G	4) Shrink fitting
	7	MgO (MG.13)	P	P	with water cooled
	8	SiO_2 GRASS	G	E	nickel substrate
Inter-electrode	9	PILEX GRASS	G	G	
Insulation	10	SiC.1BeO(SC101)	E	E	5) Non slagging with
Between	11	MgO(MG.13)	P	P	Potassium seeding
Cold Metallic	12	BN	VP	G	
Electrode	13	MgO.10BN	VP	E	
	14	MgO.65Al_2O_3	G	P	
Pitch	15	SPINE.30Si_3N_4	P	P	
1mm:NO.6~10[1]	16	Si_3N_4.5MgO	G	E	
5mm:NO.11~16[1]	17	Al_2O_3 COATING[2]	P	P	
15mm:NO.17	18	SiC.1BeO(SC101)	E	E	
24mm:NO.18					

E = Excellent, G = Good, P = Poor, VP = Very Poor

3. Insulating Wall Materials and Cooling Structure

3.1 Example of ceramic wall structure

Materials proposed for use in insulating walls were evaluated under MHD combustion gas plasma conditions, in which light oil and COM were burned. Table 1 gives the results of this evaluation. The sectional structure of a typical high-temperature wall used in this evaluation is shown in Figure 1 and the structures of the elements used in the high-temperature walls are shown in Figure 2. Figure 2(a) shows a combined type of MgO and Ni alloy. The surface is composed of MgO and the middle layer consists of an MgO-Ni alloy. Furthermore, the bottom layer, which is brazed to a cooling substratum, is composed of two types of thermal expansion buffering metals. The middle layer is connected to the first buffering layer by diffusion bonding. Figure 2(b) shows a structure in which high-purity and high-density MgO porcelain with a thickness of 5 mm is bonded to a copper plate (having a U-type section and a thickness of 1 mm) by the heat-resistant metalizing method, and a buffering layer made of an alloy of Fe and Ni (having a thickness of 3mm) is provided between the copper plate and the copper cooling substratum. Figure 2(c) shows an unbonded type cooling structure, in which Sialon ceramics

(Si_3N_4-Al_2O_3-AlN compound) is shrink fitted to a nickel cooling holder having a U-type section. These are examples of high-temperature insulating walls for use in the fuel oil-fired system. Figure 3 shows the sectional structure of an insulating wall element in which a composite of SiC ceramics and copper-carbon fiber are used as a buffering layer. This is an updated structure aimed at achieving low-temperature insulating walls and electrodes for coal-fired system. The details are described below. Table 2 gives the chemical composition of typical ceramic insulating wall materials and the manufacturing and bonding method.

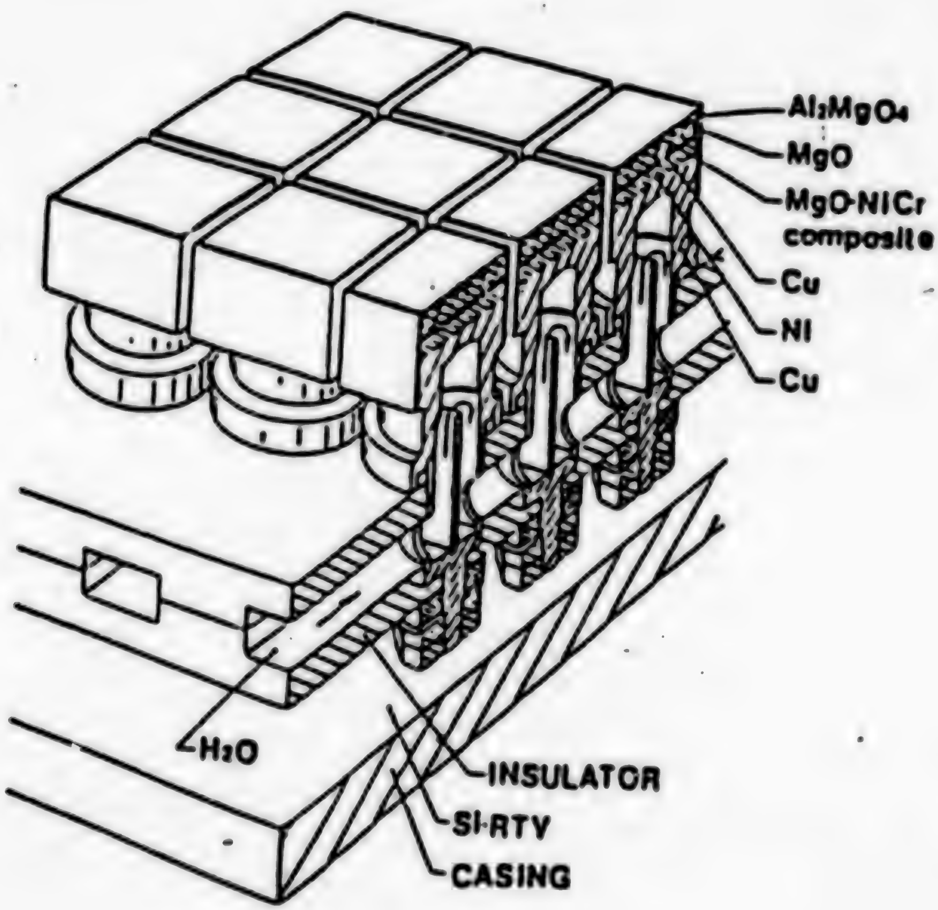

Figure 1. Insulating Wall Structure Using MgO-NiCi Composite

(a) Ceramics-metal composite compliant layer bonding type
(b) Ceramics-metal compliant layer bonding type
(c) Ceramics-metal shrink fitting type

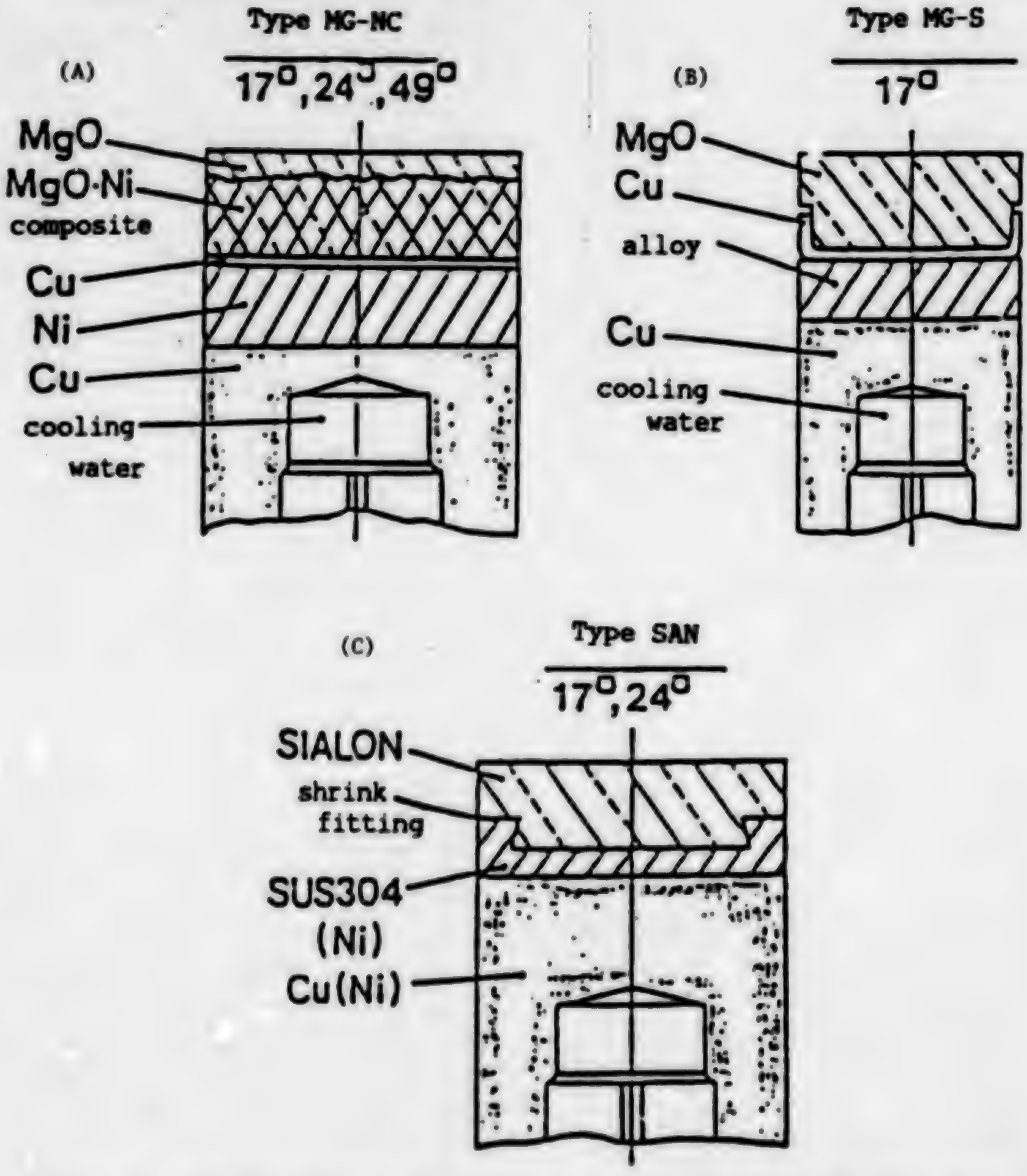

Figure 2. High Temperature Wall Magnesia and Sialon Insulating Wall Structure

3.2 Method of metalizing ceramics

Where an insulator electrically insulating space between the adjacent electrodes of an electrode wall has a width of about 1 mm, a structure in which an insulator comes into contact with the electrode cooling substratum and cools the side is employed. However, where the insulating walls have a wide area, each small piece of insulating ceramic having a tile form, is bonded to a cooling metal that, in turn, is integrated on an insulating substratum to form an insulating wall. Satisfactory bonding of ceramics to metals, therefore, is an important technology for insulating wall manufacturing. Reliable bonding techniques ensure stable operation under high heat flux conditions. A number of metalizing methods used to bond ceramics to metals--the Mo-Mn method, the silver baking method, etc--have already been applied to oxide (Al_2O_3, etc) industrial products. These metalizing techniques, however, cannot always be used with the various ceramic materials that have been manufactured on an experimental basis. Various new bonding techniques, therefore, have been studied during the development of materials during the 2nd-phase plan. Among these techniques, the heat-resistant metalizing method and the eutectic bonding method have shown superior reliability in manufacturing in MHD power generating channels. The heat-resistant metalizing method displayed an extremely stable bonding strength when used with MgO materials and the eutectic bonding method showed an extremely stable bonding strength when used with SiC materials, even in high temperature regions. Table 3 outlines the various metalizing methods of and provides an overall evaluation of the materials to which a particular metalizing method applies.

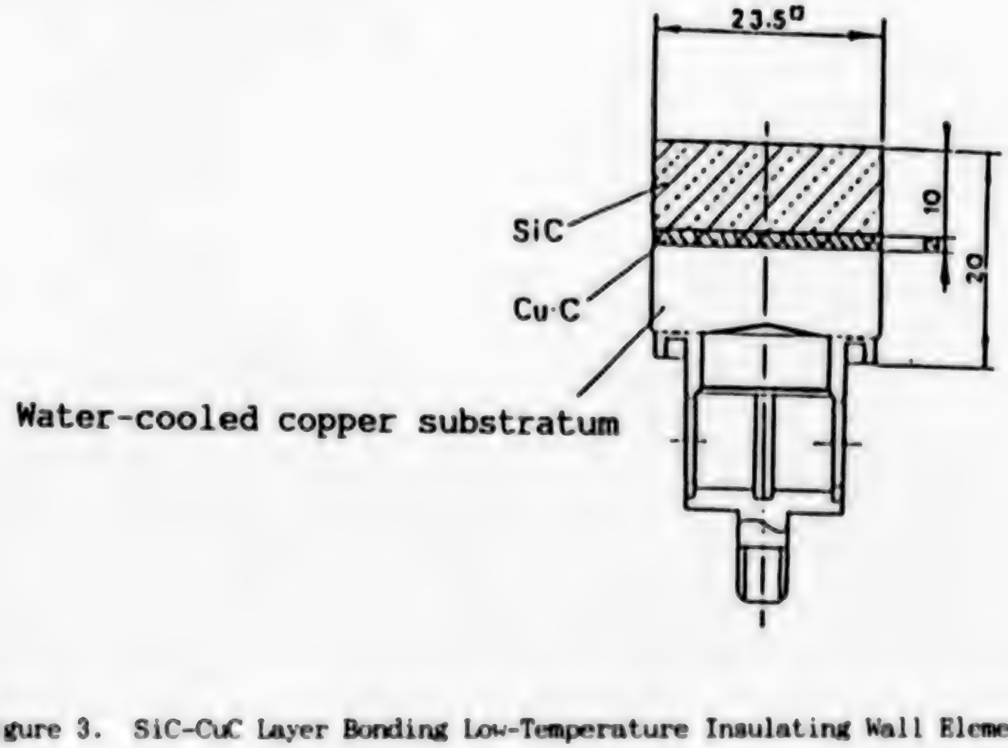

Figure 3. SiC-CuC Layer Bonding Low-Temperature Insulating Wall Element

Table 2. Ceramics for High Temperature Walls and Bonding Method

No	Material	Chemical Composition	Bulk Density (porosity)	Process	Bonding Method
1	MG-S	99.9MgO	3.55 (0.1)	CP:1.750°C	Heat resistant metalizing method
2	MG-NC	MgO&NiCr ALLOY	--	I ST SINTERING HP;1,300°C-300kg/cm² 2ND SINTERING HIP; 1,350°C-800kg/cm² (Ar)	Complex bonding method
3	SAN	$Si_4Al_2O_2N_6$.20wt %Cr_2O_3	3.16 (9.6)	IP: 1.800°C 1.000kg/cm² - 120 min	Shrink fitting method
4	CT	Cr_2O_3.3wt. %TiO_2	4.70 (3.1)	IP: 1.550°C 1.000kg/cm² 120 min	
5	SC.W (SC.101)	SiC.1wt.%BeO	3.21	HP:2.050°C-300kg/cm² - 60 min	Eutectic bonding method
6	SC.E1 (SC.501)	SiC.2wt.%AIN	3.18		
7	SC.E2 (SS)	SiC.0.3wt.%B	3.10	IP: 2.050°C-1kg/cm² - 60 min	Shrink fitting method

4. Evaluation of Insulating Wall Element Performance

4.1 Outline of splash testing equipment

The insulating walls in a commercial-size MHD power generating channel are used at a transient or a stationary heat flux of about 300 to 50W/cm². The development of such insulating walls requires a high heat flux (about 500W/cm²) generating device. For that purpose, coal-light oil mixture (COM) fired colliding jetting-type material testing equipment (splash tester) having a heat input of 1.5MW was manufactured on an experimental basis and was used to evaluate various experimental elements. In the splash testing, light oil or COM is burned using pure oxygen by means of a combustor having a heat input of 1.5MW and a pump discharge nozzle. The resulting high-temperature and

high-speed combustion gas jets collide with the test element (see Figure 4). The tester can definitively produce heat flux equivalent to that expected in a commercial-scale MHD power generator. Using the above tester, the following items were studied after conducting operations in which the rising and lowering time of heat input was comparatively small, and also after conducting rapid starting and stopping operations, with due consideration given to the severe operating conditions of commercial-scale power generators:

--Heat flux boundary of insulating wall element.

--Correlation between temperature distribution and heat flux.

--Corrosion resistivity against potassium compounds and coal slag.

--Rupture behavior based on heat flux level and heat cycle.

4.2 Heat flux boundary of various ceramics insulating elements

The relation between the heat flux and surface temperature of oxide (Al_2O_3, BeO, MgO, ZrO_2, etc) nitride and carbide (BN, Si_3N_4, Sialon <Si_3N_4-Al_2O_3-AIN>,SIC test elements and the existence or absence of thermal stress rupture studied by the splash tester are shown in Figure 5. Every high-temperature insulating wall element shows a low allowable heat flux. Even MgO walls having a comparatively superior performance show an allowable safe heat flux of 120W/cm² or less. Furthermore, it has been observed that MgO and Sialon insulating walls are sensitive to the transient thermal stresses that occur during the rising or lowering of combustor heat inputs. It has also been demonstrated that a low-temperature SiC insulating wall possesses an allowable heat flux of 500 W/cm² or more and that it is possible to construct high heat flux insulating walls.

5. Development of SiC Insulating Wall

Insulating walls are basically constructed by integrating subdivided elements and it is very important to enhance the reliability of the elements. A decrease in the number of parts due to the creation of large individual elements allows the wall structure to be simplified. It also results in an improvement in the reliability of the elements, a decrease in the loss of cooling water pressure due to the enlargement of the cooling water channels, an increase in the structural strength, etc. From these standpoints, the specific features of SiC elements were studied in detail and experiments were conducted to manufacture large-size SiC elements.

The following Describes the Various properties of SiC ceramics--which (appeared as a new insulating wall material)--having high thermal conduction insulting characteristics and the technology for bonding SiC ceramics to a copper cooling substratum. Also, the trial manufacture of a large-size SiC element, evaluation of the specific features of such large-size SiC elements using a small-size power generating channel, and the results of these undertakings are introduced below.

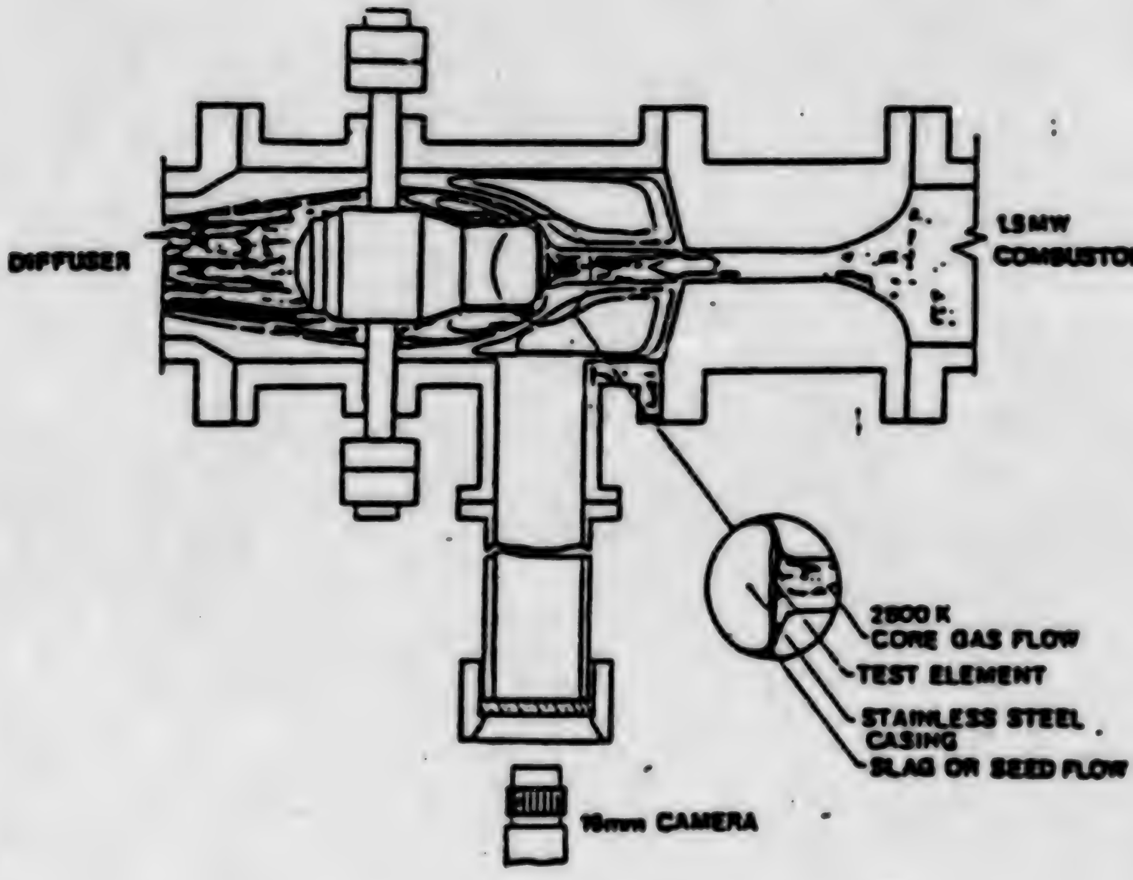

Figure 4. Structure of Splash Tester

5.1 SiC Ceramics having high thermal conduction electric insulating and method of bonding such ceramics to copper cooling substratum

Using BeO as a sintering auxiliary, Hitachi, Ltd. has developed a new SiC ceramic (HITACERAM SC101) that has extremely high thermal conductivity, electrical resistivity an. heat diffusion rate greater than that of copper. These properties also show atisfactory temperature fluctuations against rapid changes in heat load, enabl.. the manufacture of insulating walls superior in thermal shock and heat f.. esistivity. The thermal expansion coefficient of the new SiC ceramics, however, is smaller by one digit than that of a cooling substratum material (copper). Therefore, to satisfactorily bond the new SiC ceramics to a cooling substratum made of Cu, it becomes necessary to adjust the difference in thermal expansion using thermal expansion buffer, as in the case of bonding oxide ceramics to a metal.

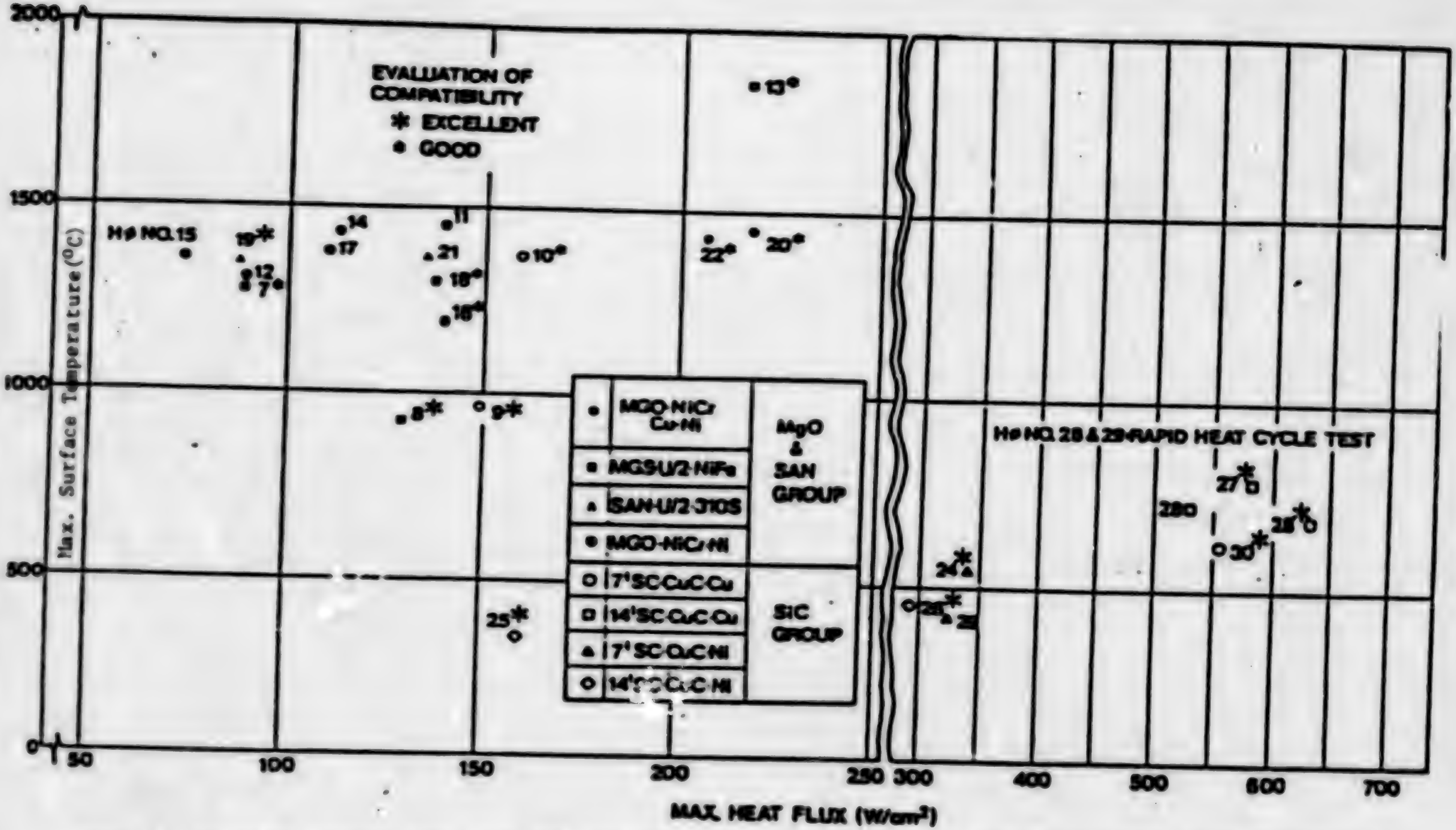

Figure 5. Relation Between Heat Flux and Surface Temperature in Various High-Temperature Power Generating Channel Wall Modules and Evaluation of Their Interrelationship

Table 7. Outline and Evaluation of Various Metallizing Methods

Metallizing method	Materials to be used	Metallizing conditions	Features	Applicable materials (Strength)	Evaluation
(1) Powder metal sintering method ([illegible] method) Mo-Mn method	Mainly Mo powder Mn, Ti, Fe	In H_2 1,300 to 1,700°C	.Many and complicated processes .Mass production is possible.	Al_2O_3-Cu, BeO-Cu	○
				Si_3N_4-W Sialon -W	△
(2) Precious metal baking method	Infinitesimally small Ag, Pt, Au and Pd powder or oxide	In Air 600 to 800°C	.Simple operation .Weak bonding strength .Unable at high temperatures.	ZrO_2-Ag $LaCrO_3$-Ag	×
(3) Activated metallizing method (Ti-Ni method)	Ti, Ni powder	Vacuum (10^{-4} to 10^{-5} mmHg) 700 to 1,300°C	.Comparatively simple operation .Difficult in mass production .Slightly low reliability	MgO-Fe-Ni ZrO_2-Ni ([illegible] kg/cm^2)	△
(4) Frit method (High melting point glass sealing method)	Melts of SiO_2, MgO, CaO, and Al_2O_3 components	In H_2 1,300 to 1,600°C	·Comparatively simple operation ·Not general	ZrO_2-Cu(Ag)	△
(5) Ni baking method	Ni	H_2 + CO 800 to 900°C	·Satisfactory anti-atmosphere and anti-chemical properties ·Weak bonding strength	ZrO_2-Ni(Ag) (330 kg/cm^2)	△
(6) Silver carbonate method	Ag_2CO_3	In air 900 to 1,000°C	·Problems in production operation	MgO-Ag (380 kg/cm^2)	✱
(7) Copper sulfide method	Cu_2S Ag_2CO_3	In air 900 to 1,100°C	·High conductivity ·Satisfactory corrosion resistance of 40% [illegible] ·Problems in production operation	La(CaCr)O_3-Ag (380 kg/cm^2)	✱
(8) Heat resistant metalizing method	Cu	In air 1,100°C	·Satisfactory anti-atmosphere and anti-chemical properties .Large bonding strength	MgO-Cu SnO_2-Cu (400 kg/cm^2)	○
(9) Complex bonding method	Ni-P	Vacuum or H_2 850 to 1,000°C	.Many and complicated processes ·Satisfactory anti-atmosphere and anti-chemical properties .Large bonding strength	MgO-NiCr(Ni) Composite-Ni ZrO_2-La(CaCr)O_3-Cu	○
(10) Eutectic bonding method	Cu-Mo	Vacuum or Ar >800°C	.Comparatively simple operation .Large bonding strength	SiC-Cu	○
Remarks	Excellent ○ Good ✱ Fair △				

Table 4. Properties of Ceramic and Buffering Materials for Insulating Walls and Electrodes

PHYSICAL CONSTANT \ MATERIAL	CERAMICS								SUBSTRATUM OR COMPLIANT LAYER				
	SiC			BeO (99%)	Al_2O_3 (99.5%)	MgO (99%)	$Cr_2O_3 \cdot 3TiO_2$	SAN-$20Cr_2O_3$	Cu	Al	Ni	SUS-304	CuC (65/35)
	SC101	SC-501	SC-SS										
DENSITY (g/cm^3)	3.2	3.15	3.1	2.9	3.8	3.26	4.7	3.16	8.9	2.7	8.9	7.82	6.1
THERMAL LINEAR EXPANSION ($\times 10^{-6}/°C$)	3.7 (RT-400)	3.8 (RT-400)	4.2 (RT-1000)	8.0	7.0	12.9	7.8	4.0	17.7	26.5	13.3	16.7	9.5–10
THERMAL CONDUCTIVITY (W/cm °C)	2.7	1.8	1.7	2.4	0.29	0.29	0.048	0.075	3.9	2.4	0.90	0.16	2.4
ELECTRICAL RESISTIVITY (Ω-cm) (AT RT)	$>10^{13}$	1	$<10^{6}$	$>10^{14}$	$>10^{14}$	$>10^{14}$	10^{2} (1000)	—	1.7×10^{-6}	2.7×10^{-6}	6.8×10^{-6}	—	3.3×10^{-1}
BENDING STRENGTH (Kg/mm^2)	45	55	45	20	30	30	15	45	—	—	—	—	50

Table 4 gives a comparison of the physical properties of sample materials (used for the tests for bonding SiC ceramics to a metal) and those of materials on the market. As a thermal stress buffer to be used for a copper substratum, a composite of copper and carbon (Cu-C composite) provided a satisfactory adjusting performance. In testing, Cu-C composite (to which was added carbon fiber having a thermal expansion coefficient that lies nearly midway between SiC and Cu at 35 percent by volume was used together with a brazing material for bonding Cu-35 percent by Wt Mn eutectic alloy (melting point: 865 - 870°C) having a thickness of 50 µm.

5.2 Trial manufacture of SiC element and its thermal characteristics

Based on the properties of SiC ceramics, it was estimated that a comparatively large element could be manufactured. Therefore, SiC ceramic element having a surface area and a thickness two times or more than those made of oxide (Al_2O_3, MgO, etc.) ceramics were manufactured. Increasing the thickness of an insulator has had a great effect on the electrical insulating performance and dielectric strength of insulating walls as well as on the surface temperatures of insulating wall elements during operation. In addition, the surface temperatures of insulating wall elements vary with the shape of the cavity of the water-cooled portion in the cooling structure, cooling substratum materials, etc. Figure 6 [not reproduced] shows the appearance of SiC elements (manufactured on an experimental basis) with different surface dimensions. It has been confirmed that the 17 mm square MgO element (whose allowable dimensions were determined by thermal stress destruction tests) has superior durability as a semihot insulating wall for clean fuel. The figure, however, shows that the size of the MgO element is much smaller than the SiC elements. Figure 7 shows a cooling structure composed of SiC elements manufactured on an experimental basis. The dimensions of each element are as follows:

--Type A: 24 X 24 mm

--Types B, C, and D: 35 X 35 mm

--Type E: 50 X 50 mm

Copper was used for the cooling substratum, except for they Type D element, which was made of stainless steel.

Figure 8 shows the changes in temperature (of the cooling substratum of each cooling structure) caused by heat flux. In the low heat flux (100 W/cm² or less) region, the buffering layer (CuC) and cooling substratum (Cu) temperatures in Type B and Type C cooling structures reached 100°C or lower and condensed water containing potassium formed inside the joints. Electric current is liable to lead from such joints and the buffering layer materials and brazed portions are corroded by potassium. However, use of the Type D stainless steel cooling substratum allows the formation of potassium hydrates to be controlled down to a heat flux region of 50W/cm² or less.

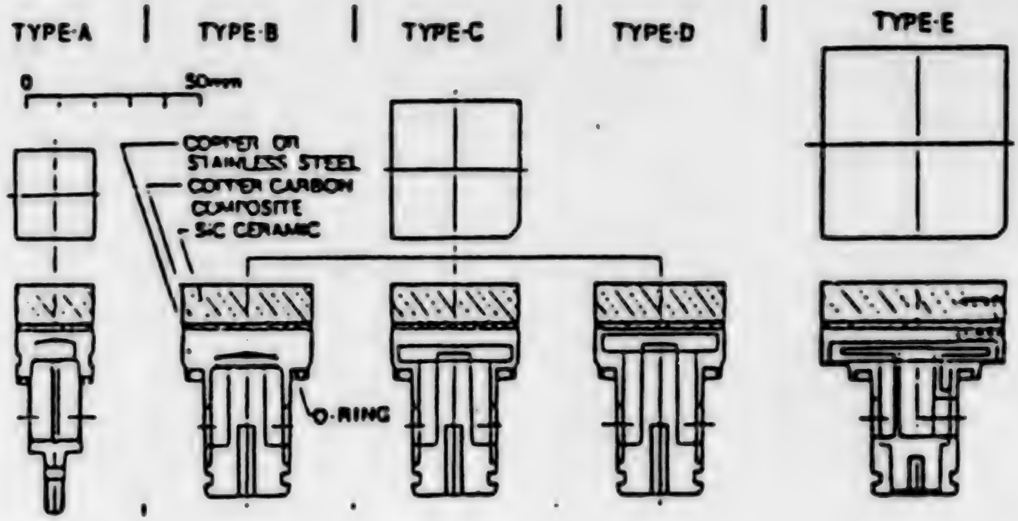

Figure 7. Cooling Structure of SiC Elements Manufactured on an Experimental Basis

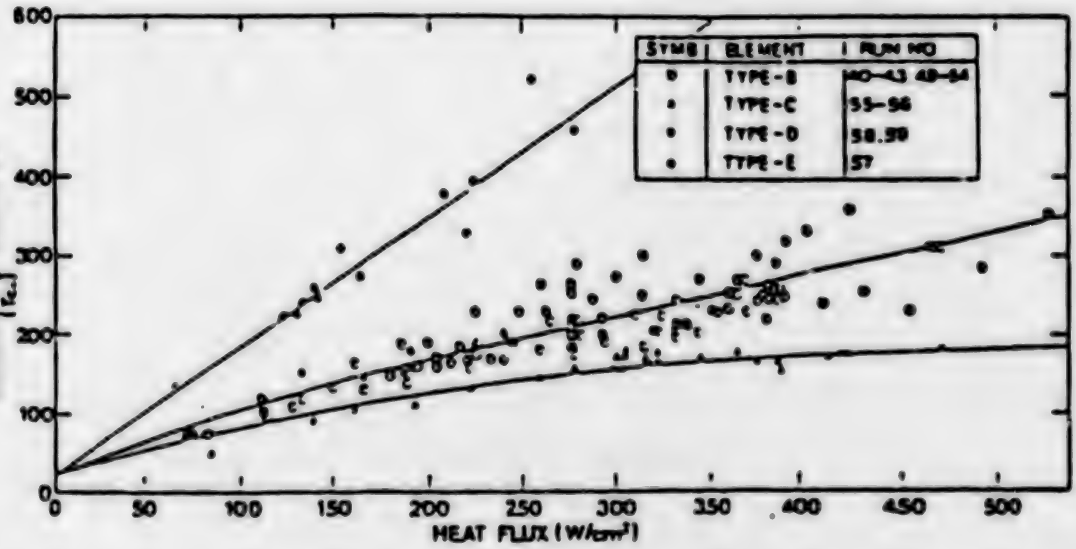

Figure 8. Changes in SiC Element (manufactured on an Experimental Basis) Water-Cooled Copper Substratum Temperature Due to Heat Flux

It should be noted, however, that the use of the above stainless steel cooling substratum causes rubber O-rings and soft brazing materials to exceed their service temperature limits to a rise in the cooling substratum temperature in the high flux region, which leads to peeling of the bonded layers or leakage of cooling water. It is necessary, therefore, to use metal O-rings for gas-sealed portions and hard brazing materials (having a high melting point) for bonding a buffering layer to a cooling substratum. For these reasons, changes in the surface temperature of the insulating wall elements (having a different cooling structure) and changes in the bonding layer temperatures were investigated against heat flux. Estimation of the above surface temperature of insulating wall elements requires that the thermal conductance of elements be ascertained. This, was obtained by measuring the heat flux and temperature gradients inside an SiC ceramic element. In other words, using the temperatures (measured by thermocouple) inside an SiC and an CuC element and the heat flux, average thermal conductances (effective thermal conductivity: λ_{eff} (W/cm°C)) of the SiC-CuC bonded layer and the SiC ceramic having a thickness of 10 mm (including CuC having a thickness of 1 mm) can be determined. The values for average thermal conductance are as follows:

--Low temperature area (less than 200°C): λ_{eff} = 1.55

--High temperature area (200°C or higher): λ_{eff} = 1.40

On the basis of these values for average thermal conductance, it becomes possible to determine the SiC element surface temperature for each cooling structure. Figure 9 shows the changes in the SiC surface temperatures arising from heat flux in the cooling structures of Types B, C, and D elements. If an allowable SiC surface temperature is determined based on anticorrosion tests (using potassium and slag) using the graph shown in Figure 9, an allowable upper limit of heat flux for each cooling structure can be obtained.

5.3 Corrosion resistivity of SiC ceramics against seed and slag

Figure 10 shows decreased in the weight of an SiC element (arising from the corrosion of potassium and coal slags against surface temperature under excessive fuel combustion conditions. Under the conditions of seeded light oil combustion, the weight of an SiC element begins to decrease at about 700°C. Under the conditions of seeded COM combustion, SiC ceramics are corroded at a surface temperature of 800°C or higher due to a reaction with potassium. The test results show that even if SiC ceramics are covered with coal slag, if potassium is present, they are limited to use at comparatively low temperatures.

Conclusion and future problems

1. The MHD power generation technology aims at developing power plants for open cycle base loads on the assumption that coal is used. The United States and the Soviet Union are making energetic efforts to realize such power plants.

2. In the United States, endurance tests extending over 1,300 hours have been conducted on MHD power generating channels. The test results show that the use of low-temperature platinum electrodes allows operations to be carried out for 8,000 hours but that insulating walls in the vicinity of electrodes undergo a degradation of insulating functions and durability due to current damage.

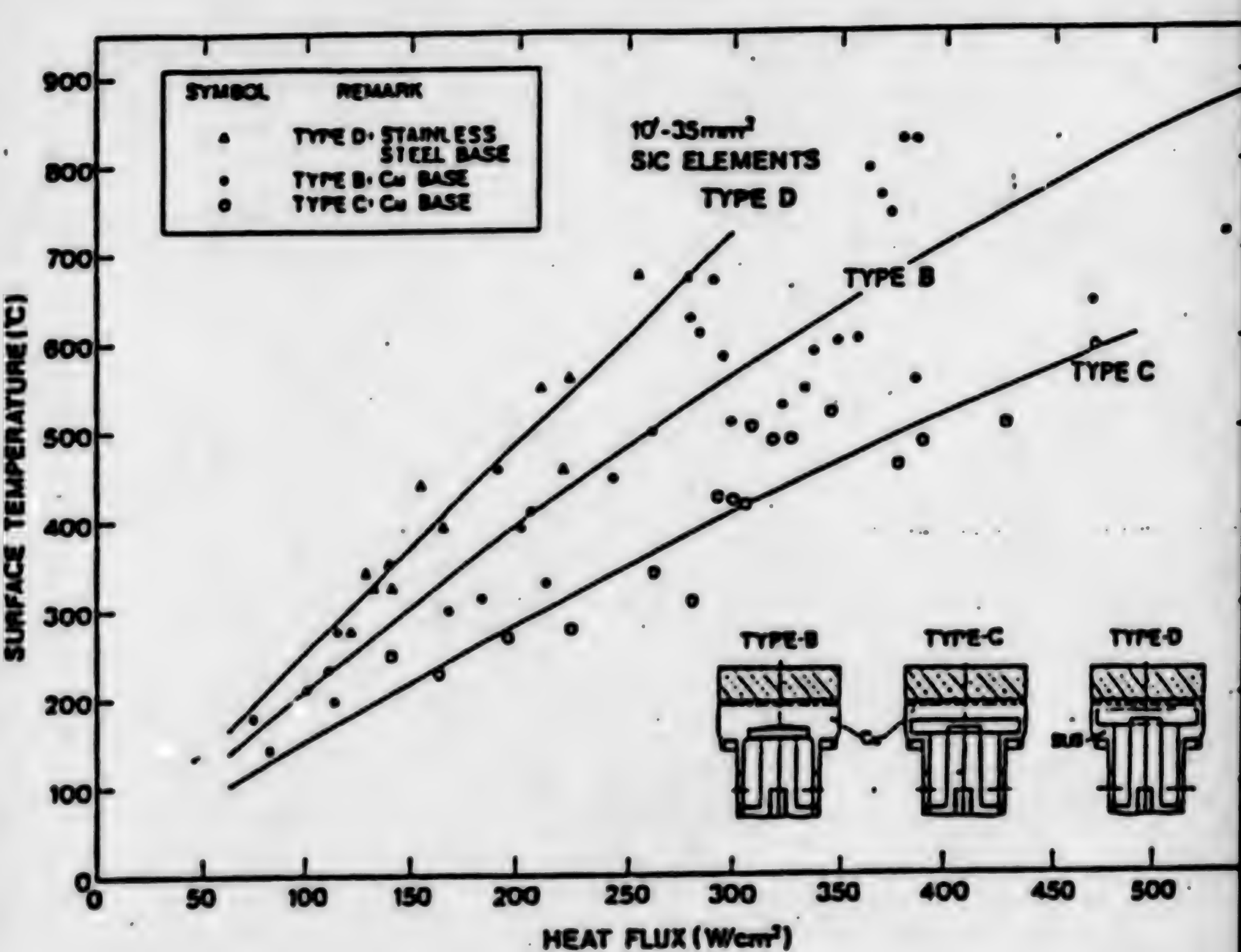

Figure 9. Changes in SiC Element Surface Temperature Due to Heat Flux

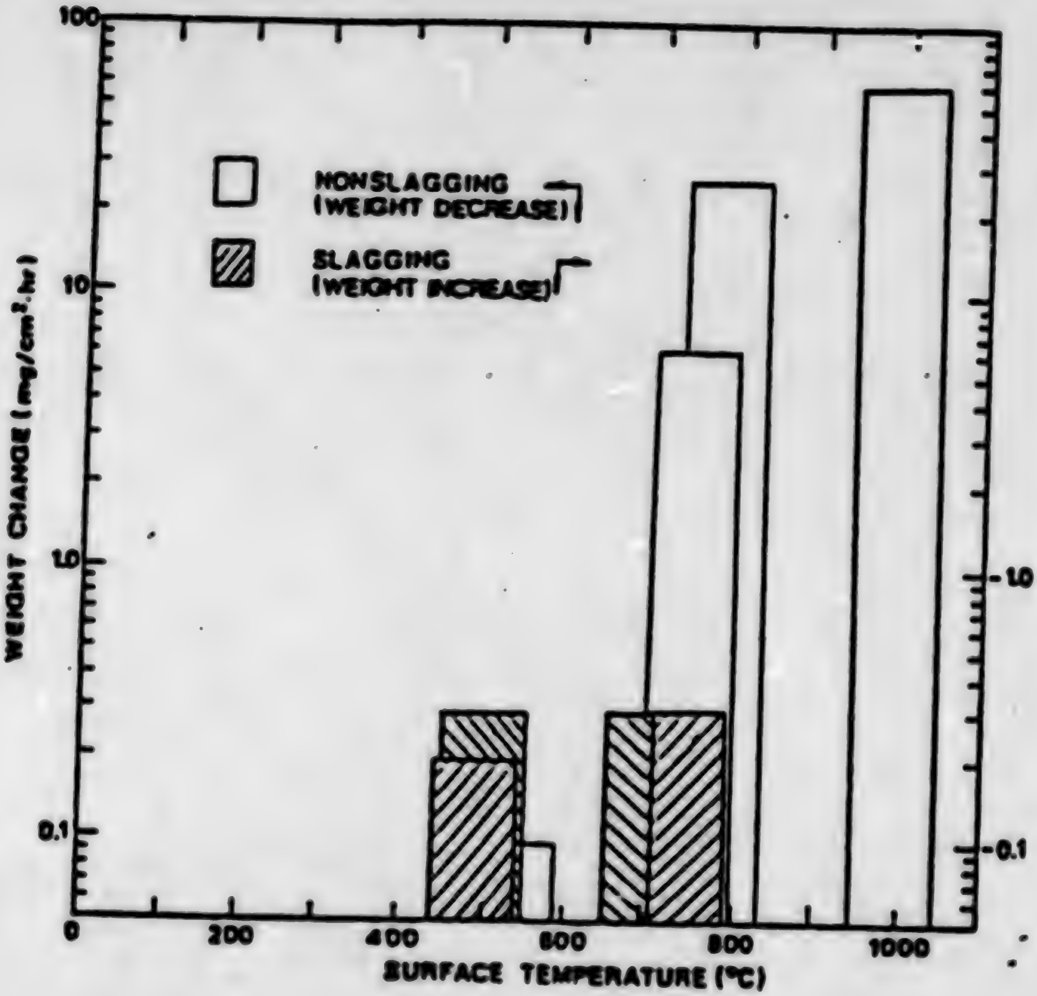

Figure 10. Weight Change of SiC Element Test Specimen Against Slag and Seed

3. It has been clarified that SiC elements developed as insulating walls for the coal-fired system have superior electrical insulating characteristics and can withstand high heat flux and severe thermal shocks.

4. If buffer layer materials and a bonding structure for bonding ceramics to metals that can be used at temperatures of 500°C or higher are developed, ultrahigh heat flux walls (1,000 W/cm² or more) can be realized. Such insulating walls can be applied to a reactor wall structure handling ultrahigh

temperature plasma as in the case of fission reactors, as well as to MHD power generators. The following items can be cited as future important tasks for the development of high temperature energy equipment:

--Creation of high heat flux ceramic materials.
--Improvement of cooling structures, including buffer layers.
--Heat recovery at high temperatures.

20153/12232

RESULTS OF SOFC FUEL CELL EXPERIMENTS DISCUSSED

43062534 Tokyo JITA NEWS in Japanese Nov 87 pp 21-27

[Article by S. Nagata, chief researcher at Energy Transportation Laboratory of Energy System Department of Electrotechnical Laboratory: "SOFC--Third Generation Fuel Cell"]

[Excerpts] Now, 1,000 kW power generation has been successfully achieved with first-generation phosphoric acid fuel cells that are domestically produced, and these cells are almost ready to enter the commercialization stage. With second-generation molten carbonate fuel cells, those concerned have succeeded in power generation of 10 kW class, and they are promoting active research and development aiming at the larger power generation[1)].

The electrolyte of the solid oxide electrolyte fuel cell (SOFC) is not liquid and paste, but solid, like other types of fuel cells, as the designation of the cell indicates. Therefore, if the electrolytic membranes produced are airtight, the pressure balance of fuel and oxidizing agent need not be so precisely established.

However, the resistivity of the stabilized zirconia used as the electrolyte is very high at a low temperature, and it begins to exhibit a low commercial value at a high temperature. Therefore, the operating temperature of the SOFC is as high as about 1,000°C, which constitutes a feature of the SOFC. At such a high temperature, the oxidization reaction speed of fuel is rapid, and a platinum catalyst such as is used in the low-temperature fuel cell is unnecessary. Also, the efficient utilization of high-temperature waste heat from the cells allows an increase in the Carnot cycle thermal efficiency of the bottoming cycle. Therefore, it is likely that the total power generation efficiency of the combined power generation can be increased more than with other types of fuel cells[2)]. Despite such advantage, it is feared that the development of the associated systems and the search for materials will entail difficulties and commercialization of the SOFC will be delayed, as the operating temperature of the SOFC is high. Consequently, the SOFC is considered the third-generation fuel cell.

In 1974, the Electrotechnical Laboratory started research and development in the high-temperature SOFC as one item under the subsection "Fuel Cell Research" under the section "Research on Hydrogen Energy Technology" as part

of the "Research on Hydrogen Energy" program of the Sunshine Project. In 1981, fuel cell research and development was brought under the control of the Moonlight Project, and the position of such R&D was changed to the subsection "Development of Element Technology" under the section "Development of SOFC" in the "Development of Fuel Cell Power Generation Technology" program. After that, the personnel concerned performed research and development mainly in power generation performance of the high-temperature SOFC, up to the experiment on power generation of 500 W class in 1986. It was decided that, starting in 1987, research and development would be carried out mainly in the airtightness and durability of cells. Furthermore, the entire research and development program is to be reviewed in 1991.

2. Principle and Efficiency of High-Temperature SOFC

A high-temperature SOFC is a fuel cell in which ceramic having oxygen ion conductivity at a high temperature is used as the electrolyte. The crystalline confirmation of ZrO_2 is shifted[5] from single oblique shape to square shape at around 1150°C, and the product is destroyed by the change in the volume during the shift of the configuration. However, if, for example, Y_2O_3 is held in solid solution in ZrO_2 and a stabilized product with a cubic crystalline configuration at a high temperature (yttria stabilized zirconia: YSZ) is produced, an oxygen ion space lattice is produced to maintain neutrality as the ion crystal, as Y (three bases) whose base is small enters the position where Zr (four bases) should originally enter. With this oxygen ion space lattice as a medium, the oxygen ion can migrate according to the motive force, and the yttria stabilized zirconia (YSZ) becomes an electrolyte having oxygen ion conductivity. The higher the temperature, the easier the migration of this ion. Figure 1 shows the principle of the SOFC.

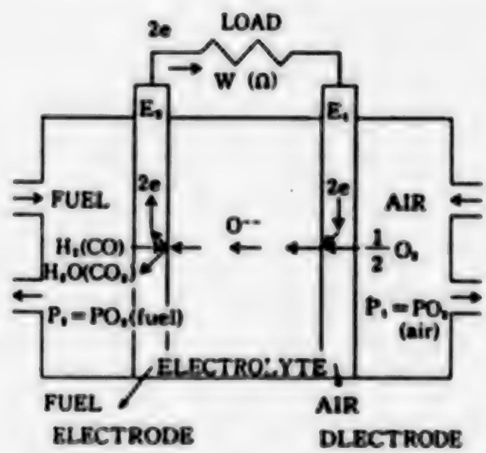

Figure 1. Principle of SOFC

If a partition wall is provided between the high oxygen atmosphere (P_1:atm) and the low oxygen atmosphere (P_2:atm) using YSZ, the difference in the chemical potential of oxygen pressure there between

$$-\Delta G = RT(\ln(P_1)-\ln(P_2))$$

exists, and becomes the motive force of migration of the oxygen ion, where T: absolute temperature (K), R: gas constant (8.31432 J/K). The YSZ membrane (electrolyte) which is pervious to the oxygen ion alone is used as a partition wall. If electrode E_1 (P_1 side: air electrode) and E_2 (P_2 side: fuel electrode) are provided at both sides of the membrane, and a gap between such two electrodes is combined at the electric load W (Ω), then the fuel (H_2) reacts with the lattice point oxygen ion on the E_2 side, produces oxidized products (H_2O), and discharges electron (2e), thereby leaving oxygen ion space lattice on the electrolyte fuel side. Consequently, YSZ is electrified from neutrality to plus. In order to make up for this, the oxygen in the air ($O_2/2$) as the oxidizing agent and electron (2e) that has flowed in the load are combined on the E_1 side, enter into the oxygen ion space lattice, and become the lattice point oxygen ion. Even if YSZ returns to stable neutrality, the concentration of the oxygen ion space lattice is high in proximity to the fuel electrode of the electrolyte and becomes low on the air electrode side. Therefore, the oxygen ion diffuses from proximity to the air electrode to that of the fuel electrode to allow the distribution of space lattice to be even, and the flow of the oxygen ion can be produced. This process continues as long as the difference in the concentration of oxygen exists with YSZ held between; namely, fuel and air is supplied to a fuel cell. This means that the migration of the oxygen ion in YSZ and also the migration of the electron in the electrodes and load as an external circuit continues. As a result, power generation is continued.

In the case where the oxygen 1 mol is transferred from the E_1 side to the E_2 side, the amount of ion transported thereby is 4 F (Faraday). Assuming that the electromotive force is E, the electric work must be equal to that of work due to the difference in pressure,

$$E \cdot 4\,F = -\Delta G,$$

where F = 1 Faraday = 96491 Coulomb. In the case where the value of W is very large compared with the internal resistance of the cell, including electric resistance of the YSZ membrane to the oxygen ion, the voltage fall in the cell can be ignored, and the voltage to be applied to W can be measured as no-load electromotive force E.

In regard to the high oxygen environment, if, for example, air is used, P_1 is equal to 0.21. If fuel gas is used as a method for producing the very thin oxygen atmosphere, the high vacuum condition of $P_2 = \sim 10^{-19}$ regarding oxygen can be simply produced at the temperature condition of combustion reaction. For example, if hydrogen is assumed to be used as fuel, the combustion of hydrogen can be expressed as follows:

$$H_2 + O_2/2 = H_2O$$

As it is assumed that the reaction speed of hydrogen will arrive at equilibrium very rapidly, the equilibrium coefficient is put as K.

$$K = P(H_2O)/(P(H_2)P_2^{0.5})$$

The electromotive force using the above formulas,

$$E = RT\ln(K)/2F + RT\ln(P(H_2)P_1^{0.5}/P(HO))/2F$$

$RT\ln(K)$ is given as the decline ($-\Delta G°$) in the standard free energy during the combustion of hydrogen gas.

At 1000°C,

$$E = 0.919 + 0.0549 \cdot \ln(P(H_2) \cdot P_2^{0.5}/P(H_2O))$$

Here, suppose that hydrogen m (mol/sec) is fed to the cell stack which is connected in series using cells in N quantities, and the load current has become I(A) and the average cell voltage V has become $V_{cell} = \langle E - I \cdot R_1 \rangle$, then the efficiency of the cell is given by the following formula, as the output of the cell stack is $V_{cell}NI$, and the energy charged into the cell is m ($-\Delta H_{298}$).

$$\eta = V_{cell}NI/m\ (-\Delta H_{298})$$

Nevertheless, R_1 is the internal resistance of the cell (including the resistance of the electrode, the concentration polarization and activation polarization as well as the resistance of the electrolytic resistance), and $-\Delta H_{298}$ is the calory (68315 x 4.184 J/mol) to be released when hydrogen 1 mol is burned at 298.15 K.

Put $V_{feed} = -\Delta H_{298}/nF$, $\eta_i = NI/nFm$ (current efficiency = fuel utilization rate), n = transport electron atomicity of fuel (2 in the case of hydrogen): then,

$$\eta = \eta_i\ V_{cell}/V_{feed}$$

Or, put the heat efficiency $\eta_t = \Delta G/\Delta H_{298}$, voltage efficiency $\eta_v = V_{cell}/(-\Delta G/nF)$, then we obtain

$$\eta = \eta_v \eta_i \eta_t$$

Because η_t is not so changed the point of research and development in fuel cells is narrowed down to the development of cells that will work (η_v: large) at a high voltage even if the choice of cells is narrowed down and η_i is increased; namely, to the development of cells from which fuel does not leak and whose internal resistance is low.

Those concerned aim at the development of cells whose fuel utilization rate is about 80 percent and whose output characteristic of 0.80 V x 0.25 A/cm^2 (=0.2 W/cm^2) can be obtained at the commercialization stage. A life of tens of thousands of hours as well as durability associated with the heat cycle is regarded as required to recover the initial investment. If hydrogen is used as fuel, we obtain η = 43 percent if V_{cell} = 0.8 V, η_i = 0.8, because V_{feed} is 1.481 V. If methane is used as feed gas, η is equal to 56 percent, because V_{feed} is 1.153 V. If methane is directly used as fuel, it is

necessary to reform the methane, because there is a risk that the electrode will be suffocated by the precipitation of carbon. Generally, the gas produced as a result of reforming the coal and hydrocarbon with steam at a high temperature is assumed as fuel. Therefore, mixed gas of hydrogen and carbon monoxide is fed to the cell as fuel gas. As the reforming reaction with coal and hydrocarbon is heat absorption reaction, the heat efficiency of the mixed gas becomes high at ΔG (reformed gas)/ΔH_{298} (pre-reforming gas) compared with the single gas, thereby increasing the efficiency of the cell, if waste heat from the cell and the burned heat of nonreacted gas are used for reforming. If carbon monoxide is included in the reformed fuel gas, the performance of the cell falls slightly, as the response of the carbon monoxide is inferior to that of hydrogen. However, the higher the operating temperature, the higher the response. Therefore, the SOFC becomes more favorable than the first-generation cell (phosphoric acid fuel cell, -200°C) and the second-generation cell (molten carbonate fuel cell, -700°C) whose operating temperatures are low. Also, as the decline in the performance of the SOFC is slight[6)], it is unnecessary to change carbon monoxide to hydrogen positively. However, it is likely that the carbon monoxide and hydrogen will eventually react with the steam (inverted reaction) which is produced, as a result of consumption as cell fuel as the internal reaction of the cell.

3. Configuration and Fabrication of High-Temperature SOFC

As indicated in the typical cross-sectional view provided in Figure 2, the Electrotechnical Laboratory produces a fuel cell stack in series on the alumina porous tube (base tube).

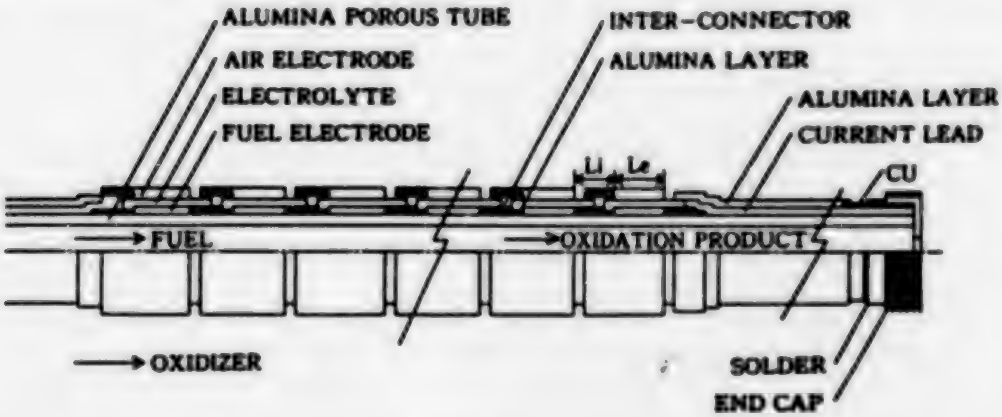

Figure 2. Cylindrical SOFC Typical Cross-Sectional View

Each composite membrane is produced by the spraying process. In the spraying conditions shown in Figure 3 [not reproduced], a copper tape (100 μm) is fastened with the loop springs, and the membrane is produced according to its predetermined pattern in regard to masking of the layer of the membrane. A slit masking process whereby the metal plate is slitted is used in some cases, such as in mass production of cells of the same type. The YSZ membrane requiring airtightness, the gas seal membrane, the oxidation resistance

membrane, and the intermediate connecting membrane linking cells in series are produced by plasma flame spraying (40 kW plasma spraying) using an argon arc jet. The electrode membrane requiring gas transmission is produced by acetylene oxygen conversion flame spraying (thermal spraying).

As the fuel electrode, NiO is sprayed and deoxidized with fuel to obtain Ni. As the air electrode, $LaCoO_3$ is used for a few hours' experimental purposes. This material is considered as showing mixed conductivity of both electron conductivity and ion conductivity[7], and is regarded to be effective for lowering polarization at the air electrode. It is reported that $LaCoO_3$ reacts with YSZ and its interfacial resistance becomes high during an experiment lasting many hours[8]. However, the resistance of $LaCoO_3$ is as small as that of oxide, and $LaCoO_3$ is effective for a few hours' experiment. Incidentally, $LaCoO_3$ forms a Perovskite crystal system, and is put in the same category as that of the oxide superconductor which has become the topic of the day. In the configuration of the cell as shown in Figure 2, current flows in a direction perpendicular to the thickness of the membrane, in the electrode membrane. Therefore, a thick, dense membrane is required from a resistance polarization aspect. But a thin, porous electrode membrane is required from the standpoint of concentration polarization. These requirements are contradictory, and the optimum thickness of the membrane must be determined experimentally. As the current in the electrolytic membrane flows almost in the direction of membrane thickness, it is necessary that the membrane be both thin and dense and also that gas does not leak from the membrane. If stabilized zirconia $(ZrO_2)_{1-x} (Y_2O_3)_x$ (X-0.09) is used, the thickness of the membrane must be reduced to about 100 μm in order to reduce the drop in the voltage in the electrolyte, as resistivity at a temperature of 1,000°C is about 10Ω cm.

The melting point of YSZ is 2,500°C--a high temperature--so it is considered very difficult to produce a dense membrane using normal plasma spray, and there remains several percent of pore distribution.

Figure 4 [not reproduced] is a cross-sectional photograph of the cell, which shows that the electrodes are porous and YSZ is very densely sprayed.

The Electrotechnical Laboratory not only continues to carry out parameter surveys on plasma spraying as a method for producing the dense YSZ membrane, but also conducts research on chemical vapor deposition (CVD), metal organic CVD (MOCVD) using metal acetonate chelate and also on laser spraying[9].

The other cell composite materials are: alumina (Al_2O_3) as an oxidation resistance membrane, a current lead and interconnector, NiAl (containing Al with Ni) as the bottom layer, $LaCrO_3$ as the interconnector top membrane, and copper sprayed on the portion where the base is installed.

Figure 5 [not reproduced] shows a completed cell stack consisting of 12 cells in series. Each of the stripped portions is a single cell. The black portion is a $LaCoO_3$ air electrode, and the white portion is YSZ used as an insulating material. The resistivity of YSZ is much higher than that of the electrode material, and the white portion plays the role of an insulating material.

4. Current Status of Research and Development

The Electrotechnical Laboratory has conducted research and development in "Production Technology" and "Power Generation Technology" for an SOFC.

The laboratory has carried out research and development in increasing performance in a few hours' power generation using a 6-element series cell stack or a 12-element series cell stack in regard to production technology. The development of air electrode material with low resistivity is indispensable for increasing power generation. Therefore, the laboratory developed $La_{1-x}M_xCoO_3$ ($0 \leqq x < 1$, M = Sr, Ca).[10]

As an example, the power generation performance of a single stack has reached the following levels at a utilization factor (equivalent to the current efficiency) of 37 percent of hydrogen fuel[11]:

Output density: 0.15 W/cm^2) = 0.59 V · 0.25 A/cm^2)
Efficiency: 15 percent
No-load voltage: 0.918 V

If the fuel utilization factor of the cell is lowered, the no-load voltage will rise, the current density will be high as against the same cell voltage, and also the output density will increase. Also, as an example of the other type cell, its no-load voltage exceeds 1.0 V.[6] However, such voltage is 1.C V or less on an average.

Regarding the durability of the cell, the Electrotechnical Laboratory has conducted 1,000 hours' durability test thereon[12].

Regarding research on the power generation systems, power generation module experimental facilities (used to study variations in cell performance by means of parallel operation), as shown in Figures 6 and 7 [not reproduced], were used to carry out the following power generation experiments: 260 W power generation (hydrogen, oxygen) experiment by means of parallel operation of a 12-cell series stack (power generation section 324 mm in length) with base tubes 21 mm ϕ in diameter and 710 mm in length; and a 460 W power generation (hydrogen, oxygen) experiment by means of parallel operation of a cell stack with base tubes 48 mm ϕ in diameter. In 1986, as an interim evaluation of research and development of the SOFC, the laboratory carried out 500 W power generation experiments under hydrogen and air gas conditions in order to summarize the cell production process by the spray method and also to evaluate the performance of the cell.

As shown in Figure 8 [not reproduced], regarding the cell and power generator rated 500 W, the conventional power generation modular experimental facility was revamped to allow a 48-cell stack to be operated in parallel.

With the cell stack, the length of the base tube was increased to 890 mm and the power generation section was set at 540 mm in length. As aforementioned, system efficiency of 50 percent or more regarding the SOFC was finally established as its development target. As the cell operating condition for

attaining such efficiency, it is required that the rated cell voltage be equal to 0.8 V (at a condition of rated current density of 250 mA/cm^2) at a fuel utilization factor of 80 percent. As cell performance using current cell production technology has not satisfied such a condition, the rated 500 W power generator was designed on the assumption that cell voltage of 0.8 V alone would be the rated condition.

In the initial stage of the experiment, the power generation characteristic as indicated in Figure 9 was obtained at a gas condition of hydrogen flow rate of 190 L/min (4 L/min/stack). The cell voltage was 0.76 V at the time of power generation of nonload voltage of 13.2 V (0.88 V/cell) and 500 W (11.4 V x 43.9 A), and the current density at such voltage was 0.063 A/cm^2 (fuel utilization factor: 2.4 percent). For information, the maximum output of the system is 1207 W (210.2 A x 5.74 V, 0.38 V/cell x 300 mA/cm^2), and the efficiency as against hydrogen fuel (fuel utilization factor: 11.4 percent) at such output is 2.9 percent.

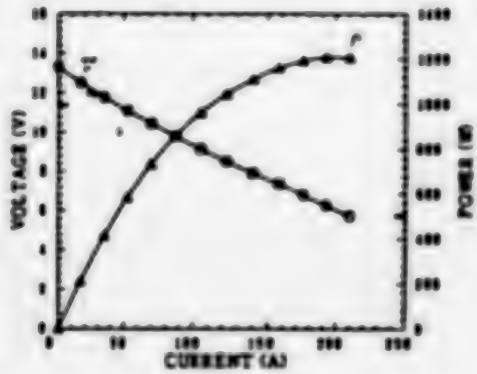

Figure 9. 500 W Power Generation Characteristic

5. Conclusion

As the results of the experiment show, good results were obtained in the experiment of the single cell stack. However, the 500 W power generation experiment revealed that the fuel utilization factor was very low. In light of these results, it is necessary to stress improvement in the airtightness of the cell.

Also, the results of the experiment of the single stack revealed that the cells developed were insufficient in respect of power generation performance, [illegible] performance is evaluated at a cell voltage of 0.8 V and current [illegible] of 0.25 A/cm^2 as the initial development target requirements. Also, a pro[illegible] with regard to the durability of the cell remains. Therefore, the laboratory will review problems with regard to power generation performance and durability, and it will promote research aimed at the development of technology closely connected to development of the 10 kW-100 kW system.

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20154/6091

CAD DEVICE DEVELOPMENT, APPLICATIONS REPORTED

43065054 Tokyo DENSHI ZAIRYO BESSATSU in Japanese Nov 87 pp 146-150

[Article by Junichi Takewaki, Kitaitami Division, Mitsubishi Electric Corporation]

[Text] The CAD device has become indispensable to LSI design due to the large amount of data handled. Recently, the CAD device for LSI use has been diversified, with various devices already in use if the entire design process is observed. The CAD device manager ensures that useless devices are not purchased and that devices are used effectively through device configuration and networking. Since the application software for LSI design has been actively discussed and much literature is already available,[1] this article will describe CAD devices themselves, with importance placed on those not discussed as frequently.

History of CAD Devices

The large machine, batch processing era continued until the end of the 1960s, focusing on computation-type jobs. Generally punch cards were used for input and lists for output. In many cases, peripheral devices, such as a plotter, were used off-line. The prototype of the current pen plotter model appeared during this period.

In the 1970s, stand-alone graphic systems using minicomputers spread and conversational processing increased. As a result, large machines gradually separated from CAD after that, except for those involving simulation and inclined toward DA. Peripheral devices kept pace with the drop in memory prices, and graphic displays made the transition from the storage scope to raster scan and from monochromatic displays to color displays. As pointing devices, digitizers and tablets came to be used. Statis plotters were also used actively.

In the 1980s, the appearance of the WS (workstation) raised conversational processing to a higher level. The WS first appeared in a form similar to that of the stand-alone system, called EWS, which bundled application programs, but the separation of the system and application programs progressed gradually. The graphic display tendency has moved from the segment

buffer method to the bit map method, and the mouse h-s become conspicuous as the plotting device.

The widespread WS use lies in the relationship between the individual and the development of network technology. At the beginning of the 1980s, much effort was directed toward connecting different devices, but toward the middle of this period, the spread of Ethernet made connecting easier. In the same way, the spread of UNIX enhanced interoperability. Network utilization has progressed from the file transfer type, in the first half of the decade, to the file-sharing type in the second half, and the connection range has ceased to be limited to between CAD devices for LSI use, expanding to include a wider area, e.g., process devices (mask creation and inspection devices, LSI testers, etc.) and CAD devices for PCB use.

The reasons for the CAD device computers becoming smaller include not only a greater orientation toward the personal processing environment, but also economic aspects. Until the middle of the 1970s, Grosch's experimental rule held and the unit price of information processing resources dropped as the computer became larger. From the midpoint of the 1970s, however, the rule failed, and in the 1980s, the resource unit price decreased as the computer became smaller. At present, if the resource unit price for a large computer is compared with that for a small computer in most advancec commodities of each class, the differences are about 1,000 times for the CPU (no significant difference between Y/MIPS and Y/kWIPS), 300 times or more for memory (Y/MB), and about double for disks (Y/GB), which show the smallest difference. The recording density on a disk surface is higher for disks for large computers, but the volumetric recording density based on a cabinet containing a power supply (GB/m^3) is about 10 times higher for disks for small computers.

Outline of CAD Devices

In general, the CAD device consists of a processor, peripheral devices, and system software. Table 1 outlines each component.

These components can also be classified into devices used directly by the user and those used indirectly by the user, and are supplied with specific functions. In this article, the former is tentatively called the user part and the latter the server part. The user part consists mainly of the MMI (man-machine interface), and the server part is subdivided into CPUs, files, prints, etc.

Since the kinds of CAD devices have increased and the situation in which different devices are mixed has become unavoidable, the network is the most important key for building the CAD environment.

Table 1. Components of CAD devices for LSI Use

Part	Processor	Peripheral devices	System software
Server part	Large computer	● Input device	OS
	Minicomputer	Image scanner	(UNIX)
	Supercomputer		
	Engine	● Output device	Network
	(CAD)	Printer	(TCP/IP)
	(AI)	Plotter	(NFS)
	(DB)	(Monochromatic, color)	DB management
	(FP)	(Pen, electrostatic)	
		● Network device	
		Port selector	
		Protocol converter	
User part	WS	o Input device	Basic tools
	Personal Computer	Mouse	Editor
		Tablet	(EMACS)
		Digitizer	(VI)
		Track ball	Window management
		Light pen	(X)
		Keyboard	(NeWS)
		● Output device	(CMW)
		Display	Shell
			Japanese input

Recent Trends

1. General purpose user part

The CAD device for LSI use has shaken free from the narrow viewpoint that it is only intended for LSI design purposes, and is being strongly requested for its capability to process all design functions on the same platform, such as that occurring at the upstream architecture level, the basic design at the downstream level, and document preparation.

2. Exclusive processing

High-speed processing and reduction of processing costs are being requested for processing with a fixed algorithm, and two main flows are noticeable. One is downsizing, in which the processing part will move to a general purpose processor with cheaper resource costs, and the other is the CAD engine based on parallel processing and the replacement of software by firmware.

3. Standardization and open system

Since the life of the CAD device is longer than the obsolescence speed of the application program, a durable device has to be selected on a long-term basis. Devices with unique processors and OSs have gradually faded, although many of them were seen in the past, and the trend toward using standard system-related items has become obvious. Furthermore, systems are now required to be not only standard, but also open, as discussed above involving the request for general purpose use.

4. Diversification

Users of the CAD device include not only LSI designers, but also application program creators and logic and circuit designers, and are tending to expand. Also, each of these groups is subdivided into skilled workers and engineers. CAD devices are also diversifying in response to this user expansion.

5. Expansion to indirect processing

So far, the CAD for LSI has been aimed only at the processing that becomes directly necessary for LSI design (for example, logical graphic input, simulation, and art work). Recently, however, the indirect processing that borders the designers' more human activities (for example, document preparation, electronic conference, DB retrieval, etc.) has come to be recognized as important, and CAD devices are also requested to deal with such indirect processing.

With the above trends as the background, the recent CAD device installation method shows clear changes. In the past, in general, the application program group was first chosen, then a suitable device was selected. Recently, however, cases in which a CAD device, including a network, is installed,

system-related items are decided upon, and suitable application programs are selected, are steadily increasing in number. Accompanying this trend, software houses which supply application programs are also shifting to standard systems, as seen in CAECO Corporation.

Enhancement of Personal Computer's Processing Capability

The processing capability of the personal computer has improved and has come to be ranked with the WS. The Whetstone value of the recent 80386 personal computer is 1,387 kW at clock frequency 16 MHz when combined with the 30387, and 2,076 kW when combined with the Weite Corporation's WTL Series. Therefore, the personal computer is provided with sufficient CPU power. Displays with graphics capabilities similar to those of the WS have also been put on the market, with those of about 1,000 x 800 mm being typically provided.

Since the RAM disk, which is difficult to use with the WS or more complex machines, is easy to use with the personal computer, the personal computer can process faster in some cases when manh I/O operations are included. Furthermore, the cost per MB is similar to that of the Winchester disk of a large machine.

Personal computer versions of LSI application programs are also increasing in number, and their packages are already on the market in the field of input editing, simulation of logic and circuit diagrams, and art work of LSIs and PCBs.[2,3] When comparing processing time by the circuit simulator SPICE, the difference between the large machine and personal computer has already been narrowed to within one position.

The WS is also waging a good fight due to the announcement of high-order devices of about 10 MIPS, the sharp drop in the price of low-order devices, and abundant application software, and the boundaries between it and the personal computer will be chaotic for the time being.[4-6]

Since a personal computer, in general, becomes obsolete faster than a WS, some people keep themselves at a distance from the former. A personal computer with abundant third parties can actually endure more long-term practical use than a large computer if option devices, such as the add-on CPU board, is fully exploited.[7]

Network

For many CAD devices to be used effectively, the network is indispensable. If no network is available, file transfers require labor, the same files are held in different places, and efficiency drops remarkably.

Networks are classified into two categories depending on the areas they cover. One is LAN (Local Area Network), which is aimed at a site, and the other is WAN (Wide Area Network), which is aimed at a wide area.

At present, the main LAN current is Ethernet. Since Ethernet allows each member to easily increase, transfer, and reduce nodes, compared with other systems such as Talkring, it is suitable for a CAD of the LSI subject to frequent changes. Almost all CAD devices for LSI use have already been made usable with Ethernet and the CAD devices connection, in many cases, if the devices supplied by third parties are fully utilized.

The first stage of LAN consists of the file transfer, as supplied by TCP/IP, and the basic communication functions, such as those represented by remote login. Since, in this stage, the file used has to be transferred, the same files have come to exist in various places and, in modification is made, confusion involving not being able to identify the newest file frequently occurs. On the other hand, during the second stage, a file-sharing function is provided by NFS, etc. Sharing one file not only allows effective use of disk space, but also reduces the number of packets, preventing the time-based concentration of packets in many cases where the entire file is not used.

Following the ASIC trend, use of WAN has also become active in the LIS field. The packet communication by X.25 is being most used. Higher-order protocols tend to be used in common with LAN. Since the development of the personal computer and WS has made it easy to have a large processing capability locally and WAN has spread, ASIC users no longer find it necessary to go to a design center each time they want design data. In a leading design center, use of the existing VAN has been taken into consideration, and general users are being entirely freed from being conscious of the network.

The problem in putting file distribution forward in a network is the code system. Not only character codes, but also floating-point notation, delimitation of a character string, and the positional relationship between the high-order and low-order bytes are important. A difference in any of these items can cause a sharp drop in a network level since no unconditional conversion technique exists.

CAD Engine

CAD engines are classified into the exclusive engine, which is the hardware version of the CAD engine for a specific application, and the general purpose engine, which combines many microprocessors and is usable for multiple purposes. Many of the CAD engines for LSI use are for multiple purposes, excluding those involving logic simulation.

As for the CAD engines involving logic simulation, the devices for parallel operation and those using real chips, developed mainly by such EWS manufacturers as Valid Corporation, are available, and the EWS power shortage relating to simulation capability, frequently pointed out 2 to 3 years ago, has been dissolved (see Photo 1 [omitted]).

Also, exclusive logic simulation engine manufacturers, such as Zycad Corporation exist.[8]

For CAD engines involving circuit simulation, the floating-point operation accelerator for parallel and pipeline processing can be fully utilized.[9]

Calma Corporation's Fast Mask Engine is available as a CAD engine involving the mask pattern.

For the electrostatic plotter, vector to raster converters of graphics (Xerox Corporation's VRC, etc.) are used.

Subjects and Future Prospects

1. Enhancement of interoperability and predictability

As the weight of conversational processing rises, the importance of interoperability and predictability, rather than that of the processing speed, has come to be recognized. Current OSs show various faults when enhancement of these items is attempted. In the United States, such new trials as MACH have been started, and the appearance of a multivender OS surpassing UNIX will be worthy of attention.

2. Strengthening of the function to deal with international environmental changes, such as t-ade friction and safety guarantee

Although, in the past, international environmental changes influenced such application programs as KIC and SPICE, the capability to deal with this problem is still clearly insufficient. It is welcome that a part of the industry, including Seiko Instruments and Electronics, Ltd., has started domestic production of CAD devices (see Photo 2 [omitted]). The trend toward the open system will be useful in enhancing the capability to deal with the international environmental changes. An important goal is to reduce black boxes by obtaining program source codes and completely digesting their contents.

3. Application of new information processing knowledge

Experience shows that when a data compression/development routine was inserted into the intput-output processing part of a logic simulation program, this insertion alone reduced the required disk quantity to one-third and the processing time to several tenths. A considerable number of application programs currently in use, such as those written mainly on the basis of processing algorithms, have margins for refinement if new information processing knowledge is applied.

4. Review of real memory computer

Some of the application programs used in CAD for LSI use require considerable processing time or a large quantity of intput-output data. However, the

size of the body of each program is not as large and, instead, is characterized by a large number of programs. At present, a large data buffer area takes up the virtual space, but this is not necessarily required and poses no problem in the transition to a real memory computer. Since some reduction is seen in the speed of the memory cost drop, but the memory cost drop is advancing at a sufficient speed, the possibility exists that the real memory computer for CAD use will be reconsidered in 1990s if a superior OS for real memory has appeared.

5. Improvement of drawing collating method

Of the CAD techniques, which mainly involve the extension of conventional technology, collation with plotted drawings exceeded the collation limits some time ago, and the apperance of an innovative technology is awaited. For those with simple collation conditions, such as geometric or electric collation, various tools have been provided but no basic settlement has yet been reached.

6. Transition to more personal environment

The WS carries out its true functions as a WS only when one or more WSs are secured for each person. In the present state in which one WS is shared by several persons, only some of the WS functions are being enjoyed. If the price transition of the WS and the high-order personal computer is taken into consideration, the main role of the WS is thought of as becoming a superpersonal computer.

Even for the supercomputer used first in the simulation system, the trend is that a medium-sized computer for use by one group is superior to a large computer shared by many people, both in cost performance and ease of use, and the personal supercomputer will become important in fields relating to LSI design.

With regard to the AI technology which is applied to the field of composition, split, and conversion of logic, the movement of the AI WS should be watched carefully (see Photo 3 [omitted]).

The CAD for LSI use seems to be accelerating its transition to a more personel environment in all aspects.

7. More total consideration for design environment

The important consideration is to minimize the occurrence of faults and errors by improving the psychological environment arrangement through the physical environment, such as the VDT filter, static electricity prevention mat, louvered illuminator, selection of the best wall color, and cable processing on a back surface and under a floor, and through reduction of asynchronous interruptions, such as telephones and meetings, which are an important factor contributing to drops in work efficiency, by replacing them with synchronous interruptions, such as electronic mails and electronic conferences.

Although in the 1990s, special processing remains for the CAD engine, etc., and only a small portion of the processing under development and in the trial-and-error stages remains left for the large computer, the development of networks should enable the user to use these devices and machines without being conscious of them, and the CAD for LSI use will become sufficiently processable in the individual environment.

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20,111/9738

RADIATION RISK EVALUATION, MINIMIZATION TECHNOLOGIES SOUGHT

Tokyo PUROMETEUSU in Japanese Nov 87 pp 78-81

[Article by Nobuaki Teraoka, Technology Development Division, Atomic Energy Bureau, Science and Technology Agency: "Research Status Quo and Problems; Detailed R&D Themes; R&D System"]

[Text] I. R&D Status Quo and Problems

A. Research on the biological effects of radiation in conventional atomic energy R&D has been regarded as falling under the developmental strategies for each "reactor type," such as fast breeder and nuclear fusion. For example, research on the biological effects of plutonium would be examined as part of the development of fast breeders, while those of tritium would come under the development of nuclear fusion. This has enhanced the importance of computing the relative biological effectiveness (RBE) of specific radiations without trying to clarify the effects of radiation across a broader spectrum.

B. As the influence of radiation on humans cannot be clarified before determining how it acts on living organisms, research in this field depends on the progress of life science research. Recent progress in the so-called field of biotechnology has brought about a revolutionary advance in life science research. Therefore, it is necessary to introduce into research on the effects of radiation the new idea of seeking clarifications on the gene and protein level by using biotechnology.

C. In Japan, R&D in this sector has been made largely in response to the needs of corporations, national laboratories and institutes and the research institutes of colleges and universities. In the future, organic cooperation between these research organizations will be needed for the systematic implementation of a wide range of research efforts from exposure dose measurement and basic animal experiments to risk evaluation and minimization.

II. Detailed R&D Themes

A. Development of Exposure Dose Evaluation Technologies

1. Research Purpose

Develop exposure dose evaluation technologies for individuals and groups involved in the development and utilization of atomic energy; develop technologies for

measuring, analyzing and monitoring the behavior of radioactive materials in the environment, the biointernal metabolism of radioactive materials, exposure dose evaluation models, radiations, radioactive nuclides and relevant materials.

2. Research Items

a. Clarification of environmental parameters for exposure dose computation technology

Clarify the principles and actual states of behavior, diffusion, migration, deposition and vital enrichment of radioactive materials in various human environments.

b. Clarify metabolic parameters for exposure dose computation technology

Animal experiments will be used to determine the effects of ingesting radioactive materials into human bodies, their distribution and discharge and the influence of various factors--age, food-chain, etc.--on them.

c. Sophistication of monitoring technology

New analyzing and measuring methods will be established for radiation and radioactive nuclides in extremely low-level or background environments. Monitoring technology for nuclear facilities and environments using these methods will be developed.

B. Development of Approaches to Biological Influence of Low Dose Radiation

1. Research Purpose

Since clarifying the biological effects of low dose radiation is crucial from the standpoint of improved safety, development of carcinogenic models, etc., research of carcinogenesis, embryological disorders and the genetic impact of low dose exposure will be carried out in order to develop new technology that can be used to pinpoint the relation between dose and effect.

2. Research Items

a. Enhancing the sophistication of molecular biological technology for risk evaluation of radiation carcinogenesis.

This will involve the cloning of human carcinogenesis sensitive genes, epidemiological research on high-risk groups through the use of a cloned carcinogenesis sensitive gene probe, the development of carcinogenic model animals by biotechnological technology, and experiments in radiation carcinogenesis.

b. Development of embryological engineering approaches to the computation of the risk of radiation-induced embryological disorders.

Recent epidemiological research on those exposed to radioactivity by the air raids on Hiroshima and Nagasaki has confirmed that a clear relation can be found between IQ and exposure dose among those having undergone internal exposure and

that exposure to relatively great doses has caused serious disorders, such as psychic delay. This research is aimed at developing manifestation mechanisms for embryological disorders—including one for the nervous system--related to prenatal exposure risk such as various malformations and preembedding germinal death.

c. Research on biotechnological technology for the computation of genetic risk due to radiation exposure.

Efforts will be made to develop and apply biotechnology, chromosomal engineering and cytoengineering techniques in animals in order to clarify specific differences in the transmission and manifestations of genetic disorders and to compute the risk for humans.

d. Development of a relative toxicological approach for radiation risk evaluation

New technology will be developed for evaluating the biological effects of transuranic elements led by plutonium taken internally. Also, application will be made of a relative toxicological approach to understanding the effects of transuranic elements on human bodies on the basis of experiments on the effects of various transuranic elements on animals.

C. Development of Radiation Risk Minimization Technology

1. Research Purpose

Thanks to advances in biotechnology and synthetic chemistry, it may soon become possible to adjust bioactive materials and to make use of cultured, stored main cells--something previously thought to be impossible. These technologies will in turn be used to develop ways to prevent radioactive materials in the environment from being accumulated in human bodies together with technology to prevent initial injuries caused by exposure from developing into diseases such as cancer.

2. Research Items

a. Development of technologies for avoiding and removing the causes of radiation risk

Research will be conducted on the removal of radioactive nuclides from food, preventing radioactive materials from entering organisms and vital decontamination of radioactive nuclides.

b. Development of biological minimization technology against radiation risk

Research will be conducted on prevention by chemical factors such as crude drug ingredients and immunity activation materials; treatment by cell proliferation/differentiation control materials such as hematopoiesis stimulation factors, carcinogenesis prevention by carcinogenesis inhibiting factors, etc.; prevention of variation by activating DNA repair genes; radiation resistance enhancement by nutritive conditions; and optimization of transplantation conditions for hematopoietic main cells and epidemic main cells.

D. Development of Risk Evaluation Technologies

1. Research Purpose

Since it is necessary to develop an approach to evaluate the potential risk of radiation disorder caused by developing a nuclear fuel cycle or nuclear fusion, it is also necessary to develop technology for the quantitative evaluation of health disorders caused by exposure. This will be done by organically joining the development of exposure dose evaluation technology with biological research on the evaluation of the biological effects of radiation.

2. Research Items

a. Development of computer codes for the logical evaluation of radiation effects and risk evaluation

An integrated analysis will be made of the data gained from animal experiments together with the results of studies on the effect of radiation on human bodies to develop an approach that can differentiate between the most accurate and uncertain risk values. From this a mathematical model will be derived that will make it possible to develop "risk evaluation computer codes." These codes will consist of dose computing codes, biological influence computing codes, cost comparison codes and risk control codes. To this end, data will be systematically structured on the results of animal experiments and epidemiological research, autogenesis ratios of radiation-induced diseases and exposure dose.

b. Development of risk measuring approaches to foster social understanding and acceptance

Here the task will be to develop quantitative approaches to measure social understanding of the magnitude of risk obtained by statistical and logical estimation (social understanding of risk) and the degree to which the technologies covered by such understanding are accepted (social acceptance).

c. Research on cost/benefit analysis of risk minimization measures and their optimization

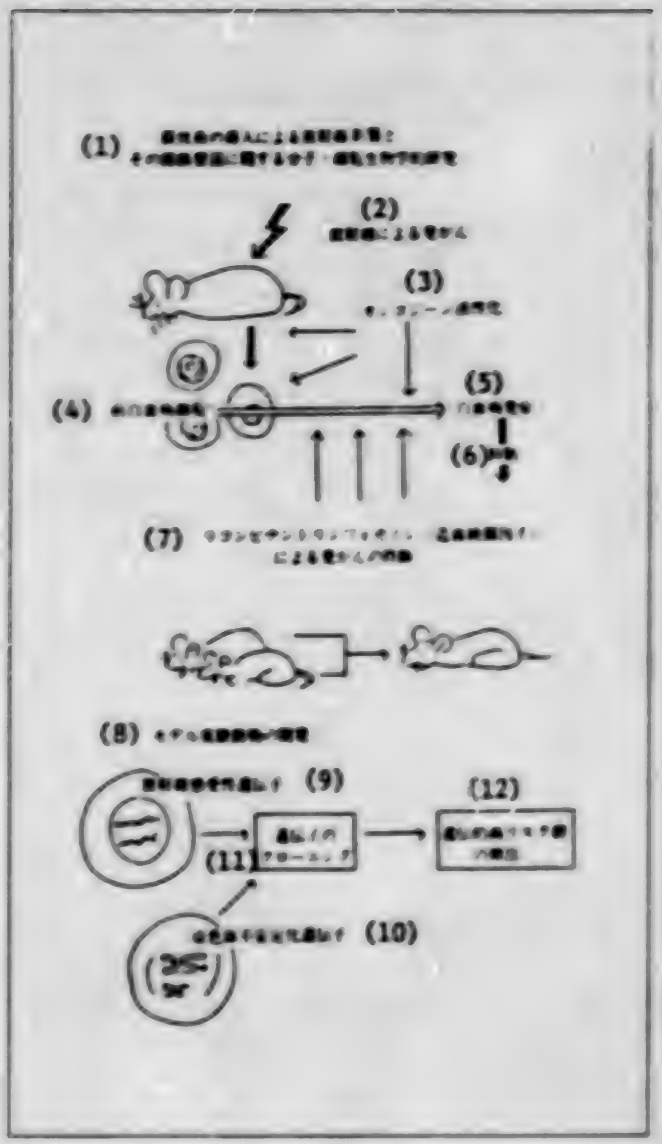
It will be necessary to develop approaches to analyze (cost/benefit analysis) and to optimize the relation between the magnitude of the risk to be minimized and the cost for radiation risk minimization measures.

III. R&D System

A. Items To Be Considered

In furtherance of the development of radiation risk evaluation and minimization technologies, it is necessary to give attention to the following points:

1. Since the R&D described above needs to be furthered efficiently through exchanges of personnel and information, effective utilization will be made of the potential of existing R&D organizations in industry, academia and the government. It is also necessary to ensure close cooperation among researchers and among research organizations.



Key:

1. Biological research on the effects of radiation on molecules and cells by introducing new technologies and its modifier factors
2. Carcinogenesis by radiation
3. Activation of oncogene
4. Preleukemia cell
5. Leukemia onset
6. Control
7. Modification of carcinogenesis by recombinant lymphokine (hematopoiesis control factor)
8. Development of model experimental animals
9. Radiation sensitive gene
10. Chromosome destabilizing gene
11. Gene cloning
12. Detection of genetically high risk groups

2. Research facilities necessary for the furtherance of comprehensive R&D will be set up in proper research organizations to allow intensive development to proceed as required based on the results obtained by researchers in industry, academia and the government.

B. Organization to Implement Research

R&D in this sector should be carried out in a radiology laboratory well equipped with research facilities and a system for implementing research. The Radiology Laboratory is scheduled to select, as its special research, biological research focusing ways to evaluate the risk of public exposure and research on ways to evaluate public exposure related to the environment and the food-chain.

1. Biological Research on Public Exposure Risk Evaluation

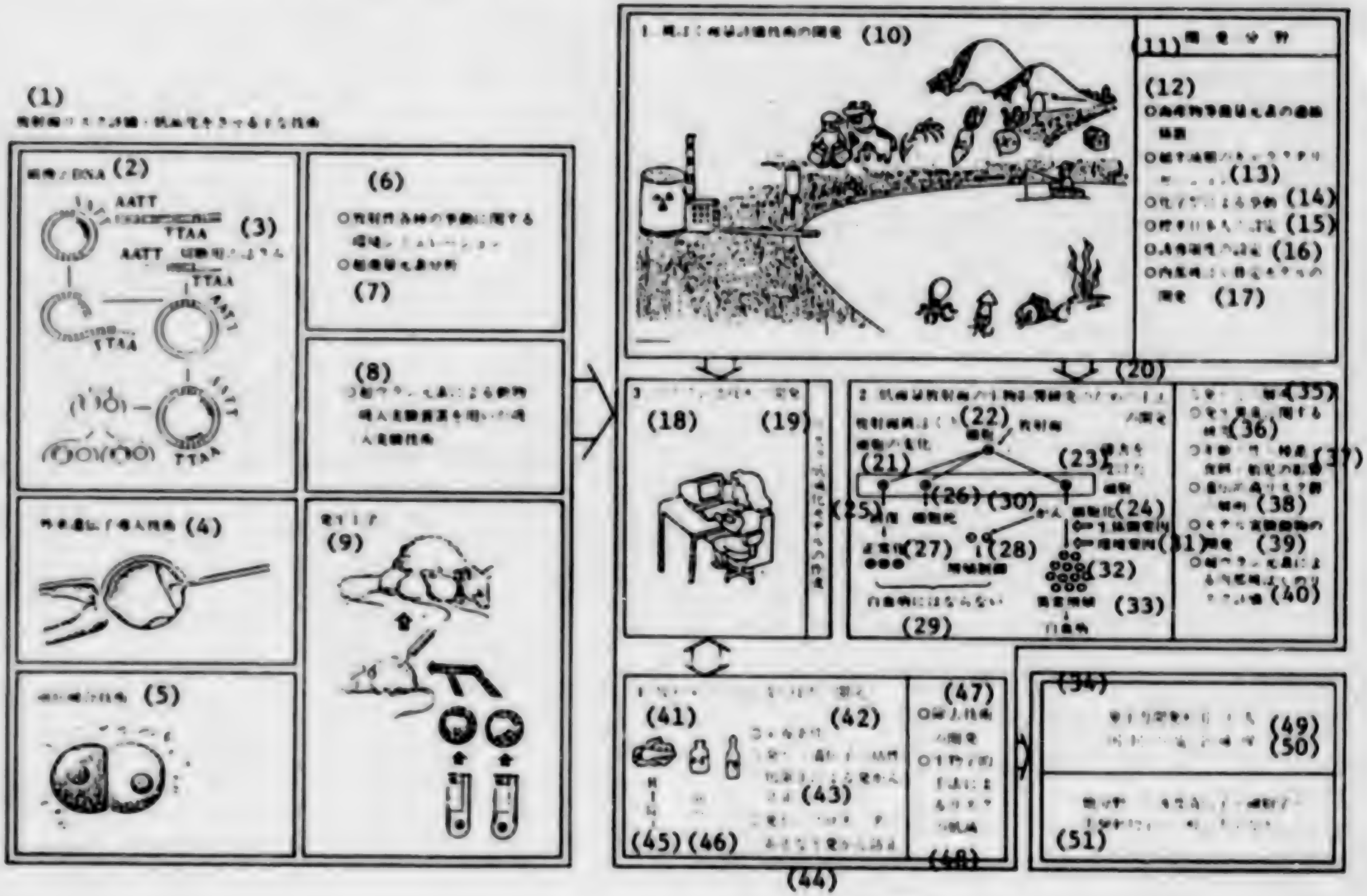
Experimental research will be made on the onset of cancer, developmental abnormality and genetic influence while considering age, sex, food, specific difference, sensitivity, quality of radiation and exposure conditions in order to clarify the relation between dose and effect. Efforts will be made to create superior model experimental animals and to introduce biological technologies. Research will also be conducted on the onset of cancer due to radiation exposure and on the mechanism of genetic influence from the standpoint of new molecular/cell biology in order to clarify the process of change that occurs within the target molecules of the target cell that become manifest as visible disorders within tissues of a solid together with ways to change and modify the process, thereby contributing to the establishment of a radiation risk minimization method as well as developing means to contribute to epidemiological research for high risk groups through the cloning of radiation sensitive genes, etc.

2. Research on Evaluating Public Exposure Related to Environment and Food-Chain

The shift of radioactive nuclides from the environment and the food chain to human bodies via inhalation or personal intake will be examined using newly introduced technologies and simulation technology to track ultramicroelements, thereby contributing to environmental safety evaluation. An attempt will be made to clarify the linkage between metabolism and the age group of radioactive nuclides and organ-reabsorbed doses by image processing technology. This will make it possible to compute the personal intake limit of radioactive materials for the public. In research organizations other than the Radiology Laboratory, research utilizing the potential accumulated in each of these areas will be shared among them all.

The Building Research Institute will undertake research into radon behavior in the residential environment, while the Meteorological Research Institute will develop an air diffusion model of radioactivity. The National Cancer Center will make molecular biological analysis of the effects of low dose radiation. In addition, with regard to radiation risk minimization technology, research will be undertaken to clarify the radiation protection mechanism by inorganic metals for organisms.

R&D on Radiation Risk Evaluation/Minimization Technologies



[Key on following page]

Key:

1. Main technologies to evaluate and minimize radiation risks
2. Recombinant DNA
3. Scissors for cutting
4. Alien gene introducing technology
5. Cell fusion technology
6. Environmental simulation related to various radioactive behaviors
7. Ultramicroelement analysis
8. Experimental inhalation technology using an experimental animal inhalation device with transuranic elements
9. Embryological engineering
10. Development of exposure dose evaluation technology
11. Development sectors
12. Enrichment factors of microelements such as marine products
13. Characterization of ultrahalf-life
14. Behavior by chemical type
15. Setting of Japanese standard
16. Setting of induction limit
17. Development of internal exposure computation
18. Development of risk evaluation technology
19. Creation of risk minimizing models
20. Development of approaches for research on biological effects of low dose
21. Radiation exposure and the change in cells
22. Cells
23. Radiation
24. Disordered cells
25. Recovery
26. Cellular death
27. Normalization
28. Proliferation control
29. Free from leukemia
30. Cells becoming cancerous
31. Vital factor
32. Environmental factor
33. Abnormal proliferation
34. Leukemia
35. Clarification of cancer onset
36. Research on developmental abnormality
37. Variations in effect due to age, sex, specific differences in food and fetal development
38. Clarification of genetically high risk groups
39. Development of model experimental animals
40. Internal exposure risk evaluation by transuranic elements
41. Development of radiation risk minimization technology

[key continued on following page]

42. Nutritive conditions
43. Prevention of onset of cancer by blocking activation of cancerous genes
44. Prevention of onset of cancer by blocking cancerous promotors
45. Rl removal
46. Avoidance
47. Development of removal technology
48. Risk minimization by biological approaches
49. Expanded applications of nuclear development
50. Enhanced national security
51. Repercussions for other sectors such as genes, cytology, experimental zoology, learning, general public nuisance, etc.

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IPCR MOLECULAR LASER URANIUM ENRICHMENT METHOD DISCUSSED

43062544 Tokyo GENSHIRYOKU IINKAI GEPPO in Japanese Nov 87 pp 6-7

[Article: "IPCR Demonstrates Effectiveness of Its Molecular Laser Method Uranium Enrichment"]

[Excerpt] Nuclear Fuel Division of Atomic Energy Bureau

For 3 years, starting in 1985, the Institute of Physical and Chemical Research [IPCR] (chief director: Tatsuoki Miyajima) has been conducting tests to demonstrate the principle of the molecular laser method in cooperation with the Power Reactor and Nuclear Fuel Development Corporation [PNC]. Up to now, the lowness of the separation factor has been an obstacle to use of the molecular method. As an interim result, the IPCR has shown experimentally that the separation factor can be enhanced by irradiating powerful 16 micron-infrared laser light to UF (uranium hexaflouride) gas cooled with a supersonic nozzle to a temperature of 100 K (minus 173°C).

1. Isotope Separation (Enrichment)

It is extremely difficult to separate isotopes having the same atomic numbers but different mass numbers. The gaseous diffusion method, the centrifuge separation method, etc, can be cited as isotope separation methods that have been put to practical use.

The laser isotope separation method uses the difference among absorption waves generated by the slight difference among masses of isotopes. This method is used to selectively excite isotopes at only one side while using laser light to convert their physiochemical characteristics, to separate these isotopes out, and to recover them.

It has been considered that even when the rate of isotopes is extremely low (for example, depleted uranium), such uranium can be enriched, because the selectivity of the laser method is great.

2. Background of Research

There are two types of laser isotope separation methods. One is an atomic method in which isotopes are processed without any change in the form of the

atoms, and the other is a molecular method in which molecular compounds containing atoms are changed to operating substances.

With regard to the laser isotope separation method used for the purpose of enriching uranium, at present research and development of an atomic method takes precedence over that of a molecular method, but the molecular method possesses many features different from those of the atmoic method. For example, 1) the UF_6 gas used in existing nuclear fuel cycles can be used as a working substance, 2) there is little restriction as to materials, and 3) a natural approach is adopted from the engineering standpoint, etc.

However, it has been considered that serious faults exist such as the delay in the development of a laser for the molecular method and the necessity of cascades having a number of stages, because the separation factor is small and the necessary enrichment performance cannot be obtained with a single stage. Therefore, the United States and France in succession reduced their research and development work on the molecular method in the early 1980's.

But the IPCR considers that the research results on the molecular method in the United States and France were not due to the essence of the molecular method, but to the following factors: 1) the separation efficiency of 238U and 235U was low because an ultraviolet laser light was used in the dissociation processes in research work carried out by the Los Alamos Scientific Laboratory [LASL] in the United States and the Centre d'Etudes Nucleaires de Saclay [CENS] of the Commissariat a la'Energie Atomique [CEA] in France, and 2) the selective excitation of 235U could not be carried out efficiently because the UF_6 gas was not cooled in the research work carried out by the United States. Also, the IPCR has devised an original method in which a separation method is combined with an adiabatic cooling process through the use of a supersonic nozzle. This separation method employs infrared multiphoton dissociation and selective excitation through the use of infrared laser light. In addition, the IPCR has carried out research and development work on the infrared laser for the molecular method.

Up to now, the IPCR has learned that the dissociative reaction caused by infrared laser of UF_6 has little secondary reaction and can be readily controlled; it has carried out research on the high-output 16 micrometer-parahydrogen Raman laser that is pivotal for the IPCR type molecular method on the basis of the world's highest result obtained by the IPCR.

3. Contents of Results

It was said that a separation factor of 2 was the limit of conventional molecular methods. But a value exceeding this figure was obtained in the above experiment by adiabatically expanding UF_6 in a supersonic nozzle type reaction unit, by cooling the UF_6 to an absolute temperature of 100 K, and by irradiating two infrared laser beams having slightly different wavelengths to the UF_6 in the vicinity of 16 micrometers.

Also, the LASL and the CENS conducted research on a molecular method in which an infrared laser and an ultraviolet laser were combined. Up to now,

it was thought that the separation factor in a single stage would not exceed 2 even if that molecular method were used.

4. Future Plans

The above test indicates that although the wavelength of the 16 micrometer laser for selective excitation was not completely tuned to the center of 235 UF_6, a value exceeding a separation factor of 2 was obtained by using the IPCR's molecular method. The IPCR is confident that if the experimental conditions are further precisely arranged (for example, the wavelength of the selective excitation is controlled, etc.), in the future sufficient enrichment performance can be obtained from a reactor in a single stage. For this reason, the IPCR is planning to continue to conduct demonstration tests on this principle and to work enthusiastically to develop the high interated-CO_2 gas laser indispensable for the next step.

20143/9274

Overview of Next Generation Industrial Technology R&D System

43063502 Tokyo JITA NEWS in Japanese Oct 87 pp 4-9

[Article by the Next Generation Industrial Technology Planning Officers' Office, Agency of Industrial Science and Technology: "Next Generation Industrial Key Technologies R&D System; Its Overview; Outline of Each Theme"]

[Text] Next Generation Industrial Key Technologies R&D System

In the present industrial society, technical innovation is the motive power for progress, which paves the way for the future. For resource-scarce Japan, in particular, technical development is crucial for improving its national living standard while maintaining the vigor of the society. This is reflected in the "International Trade and Industry Policies in the 1980s" (reported in March 1980) by the Industrial Structure Council, pointing out that for resource-scarce Japan to overcome its brittleness, it is indispensable to go forward with policies for "establishing its economic security" and "establishing the state on the basis of technologies."

MITI, as a concrete measure in response to this, initiated the "Next Generation Industrial Key Technologies R&D System" under the charge of its Agency of Industrial Science and Technology, beginning in FY 1981, thereby furthering the development of innovative key technologies indispensable for both establishing such next generation industries as aviation, space, information processing, and bioindustry, and sophisticating a wide range of existing industries.

Japanese technologies have reached the international level in terms of their application and development, many resulting from the positive introduction and improvement of technologies from Western nations, and therefore Japan still lags behind in developing basic, innovative technologies. Amid increasing criticism involving international circumstances, such as intensified trade friction, Japan is urged to go forward with R&D of key technologies, which will have a repercussive effect on a wide range of sectors, as part of its active contribution to the world economy as has been requested, and this system is aimed at meeting this very request.

Overview

1. R&D Sectors

In FY 1987, continuing from the previous year, R&D involving 13 themes in the three sectors of new materials, biotechnologies, and new functional elements will occur with the following taken into consideration:
1) extremely innovative key technologies with a great repercussive effect over a wide range; 2) those which will need a long period, about 10 years, for their R&D and have a high R&D risk due to the significant requite funds; and 3) those which are watched in Western advanced nations as R&D themes as well, and for which it is considered urgent that Japan initiate R&D.

Table 1.

New material (seven themes)	Biotechnology (three themes)	New functional elements (three themes)
Fine ceramics	Bioreactor	Superlattice structure element
High-efficiency polymeric separating film material	Cell mass culture technology	Three-dimensional circuit element
Conductive polymeric material	Recombinant DNA application technology	Bioelement
High crystalline polymeric material		
High-efficiency crystal control alloy		
Composite material		
Photoreactive material		

2. R&D Methods

(1) The "parallel developmental method" has been adopted in principle which permits multiple R&D methods to be furthered simultaneously.

(2) The entire 10-year project is divided into three stages, with each covering a few years, and evaluation of R&D situations and results being made for each stage as opposed to its present developmental target, thereby promoting rationalization in implementing R&D.

Table 2. Budgetary Transition

R&D Sector	FY 81 budget	FY 82 budget	FY 83 budget	FY 84 budget	FY 85 budget	FY 86 budget	FY 87 budget
New material	1,356	2,596	3,191	3,258	3,593	3,572 (868)	3,540 (1,190)
Biotechnology	675	1,043	1,191	1,201	1,252	1,220	1,085
New functional element	673	1,128	1,451	1,478	1,585	1,542	1,403
Total	2,714	4,786	5,850	5,952	6,445	6,513 (869)	6,043 (1,193)
Tempo of increase (percent)	--	76.3	22.2	1.8	8.3	1.1	-7.2

3. Implementation System--Cooperation from Industries, Administration, and Academia

This system is being furthered with the cooperation of industries, the government (national laboratories and institutes) and academia; i.e., in order to utilize the potential of industries, R&D is commissioned to private enterprises, while national laboratories and institutes also contribute to R&D utilizing their results to date. Cooperation has been provided from academia mainly through the Evaluation and Furtherance Committee, while some basic R&D has been commissioned to colleges and universities.

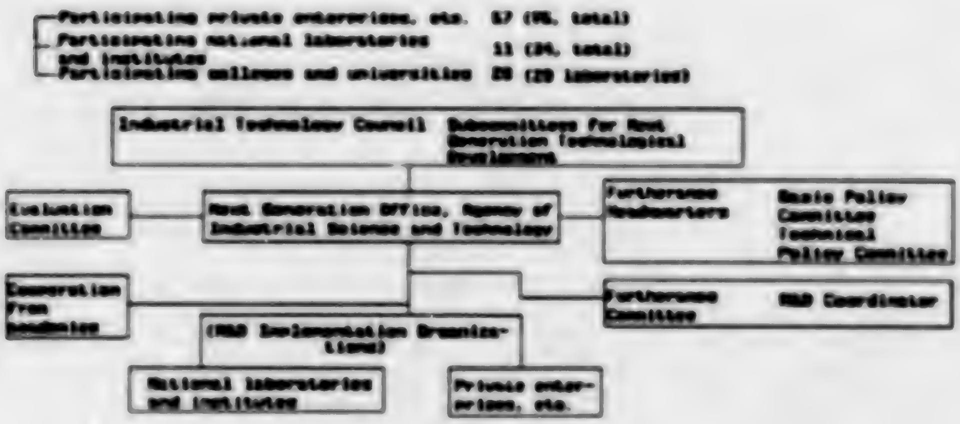

Figure 1.

Table 3. Next Generation Industrial Key Technologies R&D Schedule

Field	Item	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
New materials	Fine ceramics	Development of basic technologies in the form of specimens I			Development of key technologies using simple shape parts II				Test-manufacturing, demonstrating, and evaluating complex shape parts III							
	High efficiency polymeric separating film material	Clarification of film separation control factors I				Improvement of film performance and development of film manufacturing technology II			Demonstration of key technology for film separation III							
	Conductive polymeric material	Search for materials and clarification of conductivity mechanism I				Improved conductivity, stability and fabricability II			Demonstration of conductive materials III							
	High crystalline polymeric material	Search for materials based on molecular design I				Materialization of high elastic modulus in two- or three-dimensions II			Demonstration of high crystalline polymeric materials III							
	High-performance crystal control alloy	Development of basic technologies in the form of specimens (former period)				Test manufacturing and demonstrating complex shape parts (latter period)										
	Composite material (resin)	Development of materials, etc. I			Demonstration of forming methods II			Test manufacturing of representative structures								
	(metal)	Study of forming methods I		Development of materials and forming methods II			Forming of representative structural elements									
	(quality evaluation)	Development of key technologies for quality evaluation (former period)				Development of an evaluation method by structural elements (latter period)										
	Photoreactive material					Search for photoreactive materials and development of their forming technologies I				Improvement of material functions and demonstration of forming technologies II		Generalization of key technologies and development of multiple recording methods III				
Biotechnology	Bioreactor	Research for target microbiological enzyme I				Breeding of elite strains, development of a reaction method and total systematization II										
	Cell mass culture technology	Selection of useful cells and study of their growth factors I			Development of mediums and an optimum culture method II			Establishment of a production method for useful matters III								
	Recombinant DNA application technology	Search for target DNA and development of host vector system I				Efficient manifestation of information on target DNA II				Establishment of a production method for useful matters III						
New function elements	Superlattice structure element	Search for materials and development of crystal growth technology I				Demonstration of basic technologies and test-manufacturing of elements II			Demonstration of elements III							
	Three-dimensional circuit element	Development of laminated crystal growth technology and working process I				Demonstration of key technologies and test-manufacturing of basic elements II			Test-manufacturing of functional demonstration elements III							
	Environmental hazard-resistant element	Improvement of environmental hazard-resistance and development of the testing method I			Demonstration of integration technology II											
	Bioelement						Structuring of information processing functional models and development of basic technologies for molecular organic elements I					Test-manufacturing and evaluation of a device and elements for demonstration II				

Table 4. Implementation System for R&D of Basic Technologies for Next Generation Industries

Theme	Private organization for implementation	National laboratory and institute
Fine ceramics	Fine Ceramics Technology Research Association	Government Industrial Research Institute, Osaka Chemical Engineering Laboratory Mechanical Engineering Laboratory Government Industrial Research Institute, Kyushu Government Industrial Research Institute, Nagoya National Research Institute of Inorganic Materials
High-efficiency polymeric separating film material	Polymeric Key Technology Research Association	Chemical Engineering Laboratory Industrial Products Research Institute Research Institute for Polymers and Textiles
Conductive polymeric material	Same as above	Research Institute for Polymers and Textiles Electrochemical Laboratory
High crystalline polymeric material	Same as above	Research Institute for Polymers and Textiles
High-performance crystal control alloy	Research and Development Association of Next Generation Metals and Composite Materials	Mechanical Engineering Laboratory Metallic Materials Engineering Laboratory Government Industrial Research Institute, Nagoya

[continued]

[Continuation of Table 4]

Theme	Private organization for implementation	National laboratory and institute
Composite material	Research and Development Association of Next Generation Metals and Composite Materials	Government Industrial Research Institute, Osaka Chemical Engineering Laboratory Mechanical Engineering Laboratory Metallic Materials Engineering Laboratory Industrial Products Research Institute Research Institute for Polymers and Textiles
Photoreactive material	Sony Corp., Toray Industries, Inc., Hitachi Chemical Co., Ltd., Matsushita Electric Industrial Co., Ltd., Mitsubishi Electric Corp., and Japan Industrial Technology Association	Research Institute for Polymers and Textiles Electrotechnical Laboratory
Bioreactor	Biotechnology Development Engineering Research Association	Chemical Engineering Laboratory Research Institute for Polymers and Textiles Fermentation Research Institute
Cell mass culture	Same as above	Fermentation Research Institute
Recombinant DNA application technology	Same as above	Chemical Engineering Laboratory Research Institute for Polymers and Textiles Fermentation Research Institute
Superlattice structure element	Research and Development Association of New Functional Elements	Electrotechnical Laboratory

[continued]

[Continuation of Table 4]

Theme	Private organization for implementation	National laboratory and institute
Three-dimensional circuit element	Research and Development Association of New Functional Elements	Electrotechnical Laboratory
Bioelement	Same as above	Electrotechnical Laboratory
Environmental hazard-resistant element	Same as above	Electrotechnical Laboratory

4. Number of Patent Applications

R&D has made smooth headway so far, with the numbers of patent applications and papers published at societies both at home and abroad as of the end of March 1987, amounting to 1,381 and 3,548, respectively. With regard to R&D results, an open "Symposium on Next Generation Industrial Key Technologies" is held every year by R&D implementation organizations to promote their diffusion both at home and abroad.

Overview of Each Theme

(1) Fine Ceramics

Because of their lighter weight, hardness, and superior heat resistance, corrosion resistance, and wear resistance, fine ceramics are an indispensable material for frontier industries, such as space, aviation, atomic power, substitute energy development and high-efficiency heat engines, and much is expected of their future development. There remain, however, problems involving their brittleness and poor reliability in general, thereby hindering their wide range of diffusion as a material for high-temperature structures.

On the assumption that they are applied to main members of a turbine for coal-gasification power generation, this project aims at developing ceramics capable of withstanding ultrahigh temperatures and effectively providing high strength, high corrosion resistance, and high wear resistance, developing peripheral technologies such as nondestructive inspection and establishing an integrated key technology system, by improving their brittleness and reliability as well as workability and joinability. In FY 1987, it is planned to develop toughness-reinforced materials as well as improve strength, heat resistance, and wear resistance by optimizing individual processes of powder synthesis, forming, and sintering. Also, it is scheduled to establish reliability evaluation technology for materials to evaluate them using model-shaped parts.

(2) High-Efficiency Polymeric Separating Film Materials

Film separation technology is expected to promote high efficiency and energy savings in matter-separating processes, such as distillation, and low temperature separation in the chemical industry, permitting separation, concentration, and refining of such matters as an amino-acid's optical isomers, which have been difficult to separate because of the extreme similarity between their physical and chemical characteristics.

This project aims at establishing integrated basic technologies for film separation by developing techniques permitting highly efficient separation of liquids, gases, and other separation-resistant matters and by developing performance evaluation technology and peripheral basic technologies, such as clarification of the separation mechanism. In FY 1987, the schedule includes studying the synthesis, film manufacturing and processing of carriers capable of providing more efficient, selective separation performance, and continuing basic research involving their higher functions and the development of their evaluation technology.

(3) Conductive Polymeric Materials

Polymeric materials generally have an insulating quality, which is one of their important characteristics. On the other hand, their formation ease due to their light weight and strength, another important quality, aided by the conductivity possessed by metals, will enable them to find wider applications, resulting in a much awaited material. To reach this goal, this project aims at developing a polymeric material with conductivity as high as that of copper, which has not yet been developed.

In FY 9187, it is planned to improve control of the higher-order structure and dopant type, as well as conductivity, stability, and fabricatability, by synthesizing new materials. In addition, focusing on charge-transfer complexes, the schedule includes developing new superconductors, and explaining and evaluating their conductivity characteristics.

(4) High Crystalline Polymeric Materials

With such extremely attractive characteristics for materials as light weight and ease of formation, polymeric materials can be expected to be extremely promising structural materials if it is possible to provide them with dynamic characteristics corresponding to those of iron and aluminum.

This project intends to develop polymeric materials as strong as metals--with high strength and high elasticity--by utilizing to the utmost the dynamic characteristics originally possessed by polymers. To this end, the search for and improvement of polymers, and the development of their method of formation and evaluation technology have been advanced along with the development of high crystalline polymeric materials with high elasticity in the two- or three-dimensional form. In FY 1987, in pursuit of two- and three-dimensional materials, it is planned to conduct research into the control of a bridging polymer, high magnetic field orientation, the

development of high-rigidity materials by complexing molecules, and their processing and formation methods. Also, a study will be made of a new approach to evaluate their crystal conditions and orientation.

(5) High-Performance Crystal Control Alloys

High-performance metallic materials, superior in toughness, heat resistance and light weight, are needed for space, aviation, substitute energy development, heat engines, and ocean development. This project aims at developing three types of high-performance alloys--single crystal alloy (heat resistance), ultraplastic alloy (high rigidity, fabricatability)--with emphasis placed on heat resistance, rigidity, and high temperature strength. In FY 1987, it is scheduled to test-manufacture complex shape parts using alloys to be developed, establish their manufacturing technologies, and demonstrate molds and cores to be developed.

(6) Composite Materials

A composite material is a material obtained by combining two or more types of different materials into one, providing characteristics superior to those of the former individual ones. Composite materials with light weight, high heat resistance, and high strength are anticipated in a wide range of frontier industry sectors, led by aviation, space, and transportation machinery.

This project aims at developing high-performance composite materials require in these industrial sectors. For this goal, the development of resin composite materials (FRP), metallic composite materials (FRM), and technologies for their design and quality evaluation is ongoing.

In FY 1987, with regard to FRP, emphasis will be placed on higher performance of high heat-resistant resin and high-standard forming technology for molding the resin to be developed and initiate comprehensive evaluation tests. As to FRM, it is planned to further the development of wire preform and formation technology. Also, research will continue on sophisticated techniques for their quality evaluation and design.

(7) Photoreactive Materials

A photoreactive material is a material which provides specific functions by reversible changes in the molecular structure and coalescence situation caused by the action of light. Its applications are anticipated in sectors involving information and communications, such as ultrahigh density recording, high resolution display, and optical switches.

This project plans to develop materials which use light as a "photon," as in photochromic and PHB phenomena. To this end, the clarification of the photoreactive mechanism and basic characteristics of materials is being extended, as is the development of materials, material processing, and formulation technologies, and their evaluation technology. With regard to basic characteristics of materials, an explanation has been given for the photoreactive mechanism and molecular structure and medium effect in the

photoreaction, while as for the development of materials, the search for and design, synthesis, and manufacturing of materials which are available for ultrahigh density recording and are superior in performance stability and sensitivity responsibility are being pushed forward. As for the development of material processing and formulation technologies, efforts have been made to establish technologies for thin films, dispersion, and multiplexing, which enable material performances to be displayed to the utmost, while with regard to evaluation technology, development is occurring for performance evaluation technology for various characteristics, such as recorded density, sensitivity, and performance stability. In FY 1987, it is scheduled to search for new photoreactive materials showing photochromism and PHB phenomena, and explain their photoreactive characteristics, as well as study wavelength multiple recording regenerating technology.

(8) Bioreactors

It is planned to develop bioreactors, which involve a new processing using vital functions possessed by microorganisms and enzymes in order to materialize substantial savings in resources and energy in the main reactions produced by chemical industry, which consume a large quantity of energy--for example, the oxidizing and synthesizing reactions. To this end, research is being stressed involving materials for the immobilization of microorganisms and enzymes and their immobilization methods, improved functions of enzymes, structuring of bioreactors for a coenzyme regenerative system immobilization reducing reaction to produce mandelic acid, sorbitol, and methol, and the development of substitute bioreactors for oxidizing reaction process to produce (mucon) acid, fatty acid, acetic acid, and hydroquinol.

In FY 1987, it is scheduled to structure a minireactor system using major reactive enzymes, study factors related to continuous enzyme reactions, and conduct a basic study to establish a total system for bioreactors.

(9) Cell Mass Culture Technology

In order to promote higher added value in the chemical industry, it is planned to develop an industrial production method for useful matters by the high-density culture of animal cells, which are capable of being supplied in quantity, and stably fine chemical products whose industrial production has been impossible by the conventional synthesizing method, by utilizing vital functions of animal cells and developing substitutes for cow-fetus serums, indispensable at present for animal cell culture. To this end, human monoclonal antibodies using (namarba) cells, hybridoma, myelocytoses, and epithelial cells, as well as such useful matters as various growth factors and nonserum mediums, are being developed.

In FY 1987, it is scheduled to promote the improvement of nonserum mediums and the optimization of the culture method based on selected useful matter-producing cells, and study a cell growing method by gene migration, etc. In addition, a basic study will be made of culture technology for cells

with normal functions, as well as a study of cell proliferation control factors using vascular cells as a model.

(10) Recombinant DNA Application Technologies

It is planned to create, by manipulating DNA recombination, new microorganisms having matter-producing functions, which will be available industrially, for example, a function to efficiently produce compounds containing oxygen from material other than petroleum, and a highly efficient oxidizing function, using the host vector system approved in the DNA experiment guideline or a highly safe one yet to be developed. To this end, research is ongoing involving the development of a new host vector system and creation of strains for a high oxidation reactive process, strains highly efficient in secreting Bacillus subtilis-system human growth hormones, and high secretion yeast system.

In FY 1987, the promotion is scheduled of a high level of manifestation of various microorganisms with the use of promoters and highly functional vectors. Also, improvement will be made of a host vector system to create high oxidation reactive strains and high-secretion strains of the Bacillus subtilis system and the yeast system.

(11) Superlattice Structure Elements

In order to fabricate information processing equipment capable of providing diversified functions, such as superhigh speed processing and supermultiplex processing, it is planned to develop superlattice functional elements with extremely thin film crystals of different materials, laminated periodically in multiple layers, and superstructure lattice elements with lattice electrodes controlling the electron motion within a semiconductor thin film crystal below several thousands of angstroms. To this end, a monitor control method has been developed using vibrations of the reflected electron beam analytic strength from grown crystal surfaces and of a hot electron transistor (HET) and a resonance tunneling hot electron transistor (RHET).

In FY 1987, it is scheduled to promote sophistication of the superlattice design approach and push forward the development of key processes aimed at using such elements as technologies for crystal growth and processing. Also, evaluation of their properties and electric characteristics will be made by test-manufacturing a superlattice functional element and a superstructure lattice element.

(12) Three-Dimensional Circuit Element

In order to produce ultracompact high-performance information processing equipment, including that with multiple functions such as so-called artificial intelligence, it is planned to develop a laminated high-density element, integrating at ultrahigh density a logical and a recording function, and a laminated multifunctional element, integrating compound multiple functions including a signal converting function and a sensor function. To this end, the development has been made of synchrotron

Table 5. FY 1987 Budget for "Next Generation" (Unit: ¥million)

Item	FY 87 budget	FY 86 budget
1. New materials		
(1) Fine ceramics	1,202 (1,191)	972 (868)
(2) High-efficiency polymeric separating film material	417	539
(3) Conductive polymeric material	328	366
(4) High crystalline polymeric material	260	291
(5) High-performance crystal control alloy	522	590
(6) Composite material	634	705
(7) Photoreactive material	177	110
2. Biotechnologies		
(1) Bioreactor	373	425
(2) Cell mass culture technology	389	429
(3) Recombinant DNA application technology	323	367
3. New functional element		
(1) Superlattice structure element	442	524
(2) Three-dimensional circuit element	814	959
(3) Bioelement	147	60
4. Office expenses, etc.	16 (2)	15 (1)
Total	6,043	6,350

Note: Within parentheses are internal numbers, those for special account. In addition to the above, with regard to those related to the next generation R&D, ¥131 million has been budgeted for the alcohol monopoly business special account in order to utilize high-efficiency polymeric separating film materials in R&D related to film separating technology for this business by developing the results of next generation R&D.

radiation lithography, the beam process, and circuit structure evaluation technology, which are to be basic technologies for the projects, and of SOI technologies using laser or electron beams (laminate recrystallization technology), longitudinal wiring technology, and flattening technology.

In FY 1987, in order to materialize a multilayer laminated structure and in pursuit of high quality single crystals free from defects and grain boundaries, it is scheduled to further the sophistication of various SOI technologies and the development of microprocessing processes, such as

upper-lower layer wiring technology, test-manufacture a multilayer basic element, and conduct an evaluation of its characteristics.

(13) Bioelements

Key technologies related to bioelectronics devices will be established to materialize, in terms of engineering, the excellent information processing functions possessed by organisms by learning the manifestation mechanism of the organisms' information processing functions and unique functions of molecular organisms, such as biofunctional molecules. To this end, an explanation has been made of functions possessed by organisms, such as learning, memory, high-order recognition, and motion controllability, technologies to apply them to engineering have been developed, and the development of technology to structure an element by molecular elements capable of materializing unique functions possessed by biofunctional molecules such as plasticity, molecule recognition ability, and self-organizing ability is ongoing.

In FY 1987, in order to explain neural activities, the development of a nonintruder, simultaneous multipoint measuring method is planned, as is initiation of the development of information processing in the visual sensation system and a motion learning model of a cerebellum. Also, the development will be begin of technologies for the orientation and arrangement of functional proteins and functional polymers.

20117/9365

STA MAJOR POLICIES, BUDGET REQUESTS FOR FY88 REPORTED

43063501 Tokyo PUROMETEUSU in Japanese Nov 87 pp 82-90

[Article by General Affairs Section, Director General's Secretariat, the Science and Technology Agency: "Data: Overview of the Science and Technology Agency's Major Policies for Fiscal 1988"]

[Text] In late August, the Science and Technology Agency drew up the "STA's Major Policies for Fiscal 1988." This article introduces various programs the Science and Technology Agency intends to implement in fiscal 1988 based on these major policies.

The promotion of science and technology is one of the most important issues for our country and the world, and it is indispensable for providing stable development and a peaceful and wealthy society looking toward the 21st century. With this in mind, the government adopted a science and technology policy master plan at a cabinet meeting wherein it pointed the way for the science and technology of our country to advance in the future.

In fiscal 1988, in line with the premise of the science and technology policy master plan that "the main issue in regard to science and technology is to promote creativity centered on basic research, taking into consideration harmony between man, the society and international development," more active development of policies will be promoted and efforts will be made to implement this basic policy.

I. Overall Development of Science and Technology Administration

Along with efforts to strengthen the function of the Science and Technology Council, overall promotion of the science and technology policy will be based on the science and technology policy master plan.

1. Establishment of Science and Technology Policy Research Institute

Today, when our country's science and technology has reached the level of the advanced countries of Europe and America in many fields, science and technology policy has come to exert a crucial influence not only on research and development activity, but also on social and economic activity, international relations, etc. In order to adopt a timely and appropriate policy in response to such a situation, it is very important to promote

the strengthening of science and technology policy and the buildup of the research base. For this purpose, the Resource Investigation Institute will be abolished and the Science and Technology Policy Research Institute will be set up in the Science and Technology Agency to engage in overall systematic collection and analysis of basic data on science and technology activity and thereby engage in logical and positive investigation and research.

2. Increased Promotion of Coordinating Science and Technology Spending

With regard to the Science and Technology Council, which is the supreme deliberative body in regard to our country's science and technology policy, investigation and deliberation will be conducted in the policy committee, and basic and overall policy regarded science and technology in the country as a whole will be established in line with the science and technology policy master plan; basic guidance will be given on the promotion of priority policy, and a basic plan of research and development in the field will be set up. At the same time, the policy will be promoted in a timely manner.

At the same time, promotion of coordinating science and technology spending will be increased in order to promote overall coordination of important research work in line with the policy of the Science and Technology Council. In fiscal 1988, an international floating basic research promotion system will be newly established, and a national test research organization will reach beyond the framework of a research organization to gather internationally capable men in order to promote interdisciplinary and creative basic research. At the same time, overall promotion of important basic and leading research will be carried out on the basis of tieups among industry, academia and the government, and priority will be given to the basic research system.

II. Buildup and Strengthening of Creative and Basic Research

In the future our country, going beyond the framework of improvement and enhancement, will promote the creation of new science and technology by developing new scientific knowledge and promoting creative and basic research to develop next-generation technology. In addition, our country will actively contribute to international society by promoting the international development of science and technology from the standpoint that knowledge of science and technology is an asset of mankind as a whole.

1. Promotion of Human Frontier Science Program

Based on the fundamental philosophy of promoting creative basic research as an asset common to mankind as a whole and of contributing to international society, our country will undertake an initiative to make preparations for realization of a human frontier science program which will promote international cooperation in basic research centering on explication of the superior functions of organisms by promoting coordination of science and technology spending.

2. Expansion of International Frontier Research System

With a view to the 21st century, researchers in many fields will be gathered in order to uncover new scientific knowledge that lies buried in areas covering many fields that will become a nucleus of technical innovation. By doing so, the buildup of an international frontier research system will be promoted at the Institute of Physical and Chemical Research, where the most advanced basic research in unexplored areas will be conducted on a long-term basis in an internationally open framework.

In fiscal 1988, in addition to continued research in two fields including organism homeostasis, research to find an explanation of the thinking function will be undertaken anew.

3. Expansion of Creative Science and Technology Promotion System

In the creative science and technology promotion system of the Research Development Corporation of Japan, excellent researchers from industry, academia, the government and abroad will be organized under a project leader for a specific period. And research to create seeds of original science and technology to generate next-generation technological innovation will be promoted.

In fiscal 1988, in addition to 10 continuing problems including developmental genes, new research will be undertaken on three problems: quantum function structure, picosecond chemistry and plant information substance.

III. Promotion of International Science and Technology Cooperation

In connection with the larger role to be played by Japan in international society, international science and technology cooperation will be actively promoted in view of a situation wherein the importance of international interchange in science and technology is increasing. In view of the present situation in which voices demanding reciprocity in the field of science and technology, too, are mounting in Europe and America, the international exchange of capable men and information will be especially promoted.

1. Promotion of International Exchange of Capable Men and Information

Interchanges of capable men between advanced countries and developing countries will be promoted. In particular, invitation of researchers and acceptance of foreign researchers based on the international frontier research system and the international floating basic research promotion system will be promoted. Also, smooth acceptance of foreign researchers will be promoted by the establishment of lodging houses for foreign researchers and implementation of Japanese-language training.

In the atomic power field, with a view to promoting a subjective and active international response, expansion of the atomic power research exchange system and the atomic power controller training syrtem will be promoted, and study of an atomic power researcher dispatch/mediation system and a neighboring Asian area center concept will be undertaken.

Furthermore, an English data base with regard to bibliography generated in our country will be built up and presented overseas on-line through the international science and technology information network in tieups with the concerned agencies of the United States and West Germany; at the same time, the establishment of a machine translation system on a practical scale will be promoted.

2. Active Participation in International Cooperation Among Many Countries

Active participation in international science and technology cooperation projects such as the space station project, nuclear fusion and optical synthesis agreed upon at the summit, and technology for test evaluation of new materials will be aimed at, and at the same time, the human frontier science program will be promoted.

3. Promotion of Bilateral Cooperation

Bilateral cooperation with the United States, France, West Germany, Australia, China, Indonesia, South Korea, etc., based on science and technology cooperation agreements, will be promoted. Furthermore, an active contribution will be made to science and technology activities conducted by the United Nations, the Organization for Economic Cooperation and Development (OECD), and the International Atomic Energy Agency (IAEA).

IV. Buildup of Base for Research and Development

With the rapid development of science and technology, research and development in recent years has become highly advanced and complicated and has expanded to the boundary of the most complex areas. It has become more and more important to promote building up the research and development base in order to advance. For this purpose, active measures will be promoted for building up the research and development base in such areas as regional science and technology contributing to vitalization of a region, research interchanges between different fields or beyond the framework of research organizations, large-scale joint-use facilities for advanced and basic research, communication of science and technology information, research material on gene resources, etc., and for a tax system and funding to promote science and technology.

1. Promotion of Regional Science and Technology

(1) Promoting Upgrading of Regional Science and Development

In order to promote the upgrading of the research and development function in a region while making maximum use of the potential there, a model region will be selected. A research information network will be established within the region and between the region and Tsukuba Science City, and at the same time, mainly based on this, personnel interchange, joint research and commercialization of new technology will be promoted.

Furthermore, with regard to ocean science and technology, regional joint research and development efforts in which state and local public bodies cooperate will be promoted.

(2) Promotion of Leading and Basic Regional Science and Technology Facility Buildup

In response to requests from a region, social capital will be built up utilizing resources, natural conditions, etc., independently existing in the region through science and technology based on an interest-free loan from the Japan Development Bank, preferential treatment in tax system, etc. In order to promote the buildup of a leading and basic science and technology facility contributing to enhancement of the regional economy as a whole and to strengthening our country's science and technology base, efforts aimed at building up a leading and basic regional science and technology facility will be promoted.

2. Promotion of Large-Scale Synchrotron Radiation (SOR) Facility Project

The large-scale synchrotron radiation (SOR) facility has brought remarkable results centering on basic research in a wide range of fields such as substance/material science and technology, life science, information/ electronic science and technology, and atomic energy research and development. Furthermore, the SOR facility is an important research facility contributing to the development of optical science and technology,, and it should be built up as an international level joint-use research facility. For this purpose, research and development will be built up and strengthened jointly by the Institute of Physical and Chemical Research and the Japan Atomic Energy Research Institute, and at the same time, design and research, etc., will be undertaken.

3. Promotion of Research Exchange Among Industry, Academia and Government

(1) Promotion of Research Exchange Through Joint Research, Etc.

In order to promote joint research with the private sector, etc., at test and research organs attached to the Science and Technology Agency, the buildup of a specially designated government and private sector joint research system will be promoted, and effective use of research based on a guest researcher system will be promoted. Furthermore, the participation of government researchers in science academies at home and abroad and in research meetings, as well as their dispatch for domestic and overseas study, will continue to be promoted.

(2) Promotion of Hi-Tech Consortium System

Based on basic patents as a result of research by the creative science and technology promotion system etc., while the vitality of enterprises will be utilized through the participation of researchers of national test research organs, etc., centering on the Research Development Corporation of Japan and private enterprises of various kinds, a hi-tech consortium system will continue to be promoted in order to advance the development of new technologies through peripheral patents, etc.

(3) Promotion of Commercialization of New Technology

The Research Development Corporation of Japan will, by commissioned development or acting as a go-between, promote the commercialization of new technology utilizing excellent testing and research results.

4. Promotion of Communicating Science and Technology Information

In order to help promote research in advanced/important science and technology fields, the Japan Information Center of Science and Technology will expand the bibliography data base, build up the fact data base of numerical data, etc., and present information through the on-line method, and it will promote the development of the new on-line presentation system (JOIS-III) that will make possible comprehensive utilization of the bibliography and the fact data bases. In addition, by promoting international communication of science and technology information, the buildup of a nationwide communication system of science and technology information (NIST) will be promoted.

5. Buildup of Collection, Preservation and Presentation System for Gene Resources, Etc.

In order to rapidly strengthen the system for collecting, preserving and presenting gene resources, whose buildup lags behind that of many foreign countries, the Institute of Physical and Chemical Research will promote building up a cell/gene preservation facility (gene bank building), and at the same time, it will promote the collection and preservation of cells/genes in order to begin presentation work. Furthermore, efforts to preserve the micro-organism system will be promoted, and a survey will be conducted on the buildup of information on plant gene resources.

6. Support in Aspects of Tax System and Funding

In developing science and technology, because it is important to utilize the vitality of the private sector, the buildup of a tax system related to science and technology such as extension of the additional test research spending tax exemption system and establishment of a tax system to develop regional science and technology will be promoted. Also, measures will be taken to support funding such as interest-free loans from the Japan Development Bank for the purpose of developing regional science and technology.

V. Promotion of Research and Development of Advanced/Important Science and Technology Fields

1. Promotion of Atomic Energy Research, Development and Utilization, and Safety Measures

With regard to research, development and utilization of atomic energy, based on the long-term new atomic energy development and utilization plan adopted in June, atomic energy has been positioned as a key energy in our country, and its establishment and steady development will be promoted

through the understanding and cooperation of the people. For this purpose, in addition to building up and further strengthening safety maintenance measures, policies will be adopted in regard to the location of atomic energy facilities, etc., establishment of a nuclear fuel cycle, development of a new-type power reactor, research and development of nuclear fusion, etc. Also, creative and innovative atomic energy research leading to new technological innovation as well as active contributions to international society as a nation to promote atomic energy utilization will be promoted.

(1) Buildup and Strengthening of Atomic Energy Safety Measures and Nuclear Nonproliferation Response

In promoting research, development and utilization of atomic energy, so far regulation and control have been strict, and carefully thought-out measures have been taken to insure safety. In view of the accident at the Chernobyl nuclear power plant in the Soviet Union, in the future attention must be devoted to administration of atomic energy safety regulations, the buildup of investigation and analysis of atomic energy facility accidents and mishaps at home and abroad, the strengthening of the framework for monitoring environmental radioactivity, the buildup of disaster prevention measures, the promotion of safety research, the strengthening of measures to prevent radiation sickness, etc. Thus, the further buildup and strengthening of measures for atomic energy safety will be promoted, along with enhancement of the people's understanding of these measures.

In addition, in order to promote an accurate and effective response to the advancement of atomic energy research, the establishment of various standards will be promoted in regard to the development and commercial utilization of the nuclear fuel cycle and the development of a new-type power reactor.

In addition to promoting the buildup and strengthening of security measures based on the nuclear nonproliferation treaty, etc., our country's nuclear substance protection system will be further strengthened, and at the same time, necessary action including legal action will be taken to join the Nuclear Substance Protection Treaty.

(2) Establishment of Nuclear Fuel Cycle

In order to establish an independent nuclear fuel cycle, active measures will be promoted for development of radioactive waste products treatment and disposal, undertaking surveying and prospecting for uranium overseas, construction and operation of a uranium enrichment plant, technological development of laser-method uranium enrichment, development of reprocessing technology, research on fuel reprocessing technology for a fast breeder reactor, and the buildup and strengthening of geologic disposal measures for high-level radioactive waste, and at the same time, measures necessary for promoting the plan to set up location of the nuclear fuel cycle facility in the private sector will be taken so that its smooth commercialization can be promoted.

(3) Promotion of Development of New-Type Power Reactor

With regard to a fast breeder reactor, construction of the "Monju" original-type reactor will continue to be promoted, and at the same time, necessary research and development will be conducted, including irradiation testing, using the "Joyo" experimental reactor.

With regard to a new-type converter reactor, data on the operating experience of the "Fugen" original reactor will accumulate, and related research and development will be promoted in order to advance the subsequent project for proving the reactor.

(4) Promotion of Leading Projects Such as Nuclear Fusion

With regard to nuclear fusion, experiments using the critical plasma tester (JT-60) will be continued, and work will be carried out on the equipment to upgrade performance. Also, research related to plasma sealing, reactor engineering, etc., will continue to be promoted, and cooperation in the international thermonuclear fusion experimental reactor (ITER) project, etc., will be actively promoted.

With regard to radiation utilization, radiation hi-tech research for the purpose of upgrading radiation utilization technology will be promoted, as well as construction of heavy particle cancer treatment equipment and heavy-ion accelerator research and experimentation.

With regard to research and development of a nuclear-powered ship, effective experiments on the nuclear-powered ship "Mutsu" will be conducted in order to obtain knowledge and data indispensable for future research and development of a ship reactor on the basis of the previously adopted policy. Construction of the new mooring harbor Sekinehama necessary for that purpose will be promoted, as will research to improve the ship reactor, design evaluation research, etc.

Establishment of a base for high-temperature gas reactor technology and upgrading of the technology will be promoted, and construction of a high-temperature engineering test research reactor for the purpose of promoting leading basic research in regard to high-temperature engineering will be undertaken.

(5) Promotion of Basic Technology Development

The development of basic technology that will make it possible to upgrade atomic energy technology and generate new technological innovation will be promoted in a tie-up among industry, academia and the government. For this purpose, research on technology to create and evaluate materials for atomic energy, technology to give "smart" functions to atomic energy facilities, application of laser technology for atomic energy, and technology to evaluate and reduce the risk of radiation will be promoted with the close cooperation of the Japan Atomic Energy Research Institute, the Power Reactor and Nuclear Fuel Development Corporation, the Institute of Physical and Chemical Research, the National Research Institutes, etc.

Basic research in such fields as that on nuclear data using a tandem accelerator and on a high-conversion light-water reactor will be built up, and joint utilization of atomic energy facilities and joint research among industry, academia and the government will be promoted.

(6) Facilitation of Locating Atomic Energy Facilities

In order to facilitate the locating of atomic energy facilities, measures will be taken for the benefit of people living in the vicinity, by such means as promoting the granting of a subsidy for electric power source establishment in a location based on three electric power source laws, and enlightenment activity concerning such means as the use of a monitoring system will be promoted. In order to help settle the issue of atomic energy power generation, research and development of technology for the decommissioning of an atomic energy power generation facility will be promoted.

2. Promotion of Space Development and Utilization

With regard to the development and utilization of space as a new area of activity for mankind, while reliability and safety on the basis of independent technological development centering on National Space Development Agency will be maintained, the development of artificial satellites in the field of actual utilization of space such as communications broadcasts, weather observation, ocean observation and earth resource observation, and of a space transport system of rockets to launch the artifi-ial satellites will be promoted. At the same time, participation in the space station project to promote the expansion of space activity will be promoted.

(1) Promotion of Development and Launching Artificial Satellites

With regard to the communications and broadcast field, the research and development of an experimental data relay/tracking satellite (EDRTS) in order to develop data relay/tracking technology using a geostationary satellite will be initiated, while the development of communications satellite No 3b (CS-3b, scheduled to be launched in fiscal 1988) and broadcast satellites No 3a and No 3b (BS-3a and BS-3b, scheduled to be launched in fiscal 1990 and 1991, respectively) will continue to be promoted.

In the observation field, the development of marine observation satellite No 1b (MOS-1b, scheduled to be launched in fiscal 1989) to continuously observe ocean phenomena centering on the color and temperature of the ocean surface, the development of an earth observation platform technology satellite (ADEOS, scheduled to be launched in fiscal 1993) with the aim of developing technology necessary for a future platform-type satellite and the development of geostationary meteorological satellite No 5 (GMS-5, scheduled to be launched in fiscal 1993) will be undertaken, while the development of geostationary meteorological satellite No 4 (GMS-4, scheduled to be launched in fiscal 1989) and earth resource satellite No 1 (ERS-1, scheduled to be launched in fiscal 1991) will continue to be promoted.

Also, the development of an engineering test satellite (ETS-VI, scheduled to be launched in fiscal 1992) will continue to be promoted.

(2) Promotion of Development of Space Transport System Such as Rockets

The development of the H-1 rocket with the capacity to launch a geostationary satellite weighing about 550 kg will be promoted. Also, in order to meet the demand for launching a large artificial satellite in the 1990's, with regard to the H-II rocket with a capacity to launch an approximately 2-ton geostationary satellite, development aimed at launching test machine No 1 in fiscal 1991 will continue to be promoted. Furthermore, in order to meet the demand for recovering products that result from space experiments, research will be conducted on a winged space shuttle aircraft of the H-II rocket launch-type (HOPE).

(3) Comprehensive Promotion of Space Station Project

A space station would greatly increase mankind's capability for space activity and would make possible new space activity. It would also be important in such areas as the development of space science, the promotion of utilization of space environment, the upgrading of advanced science and technology, and the promotion of international cooperation.

With regard to the space station project, the development of the space station-attached type experimental module (JEM), scheduled to be launched in fiscal 1995, will continue to be promoted. Also, the buildup of a framework for international cooperation on the space station project after the development stage will be promoted.

Furthermore, there will be continued development of the reusable space experiment/observation Free Flyer, the goal of which is to conduct various space observations and experiments and to enhance reliability of the exposed section of the experimental module and on-board joint experiment equipment, aiming at a launch by the H-II rocket in fiscal 1992. Research will also be conducted to develop a crew training system, as will research on space robot technology for unmanned operations in orbit.

With regard to the field of space experiments, coordination will be carried out with the United States so that scientists and technicians of our country can travel aboard the U.S. shuttle soon in order to conduct primary materials experiments (FMPT). After that, development of the necessary experimentation system and airborne training of scientists and technicians will be promoted. In order to participate in the primary international microgravity experiment room project (IML-1), the development of airborne experimentation equipment will be undertaken.

(4) Promotion of Basic and Leading Research, Etc.

At the Aerospace Technology Research Institute, as a part of the research and development of innovative aerospace transport component technology, the strengthening of research on component technology for a reusable model

space shuttle aircraft of the winged horizontal takeoff and landing type will be promoted, while research on liquid oxygen and liquid hydrogen rocket engine components for use of large rockets will continue to be promoted.

Also, the buildup of a system aimed at promoting effective collection/ utilization of technological information at home and abroad in the aerospace field will be promoted.

In addition, the buildup of a preferential treatment and loan system based on the tax system for space development and utilization will be promoted, along with research on space utilization centering on space environment utilization and earth observation.

3. Promotion of Ocean Development

In order to direct man toward the ocean as a new area activity and to promote multilateral research and utilization of theocean area surrounding our country, comprehensive promotion of ocean development with the cooperation of the agencies concerned centering on the Ocean Science and Technology Center as well as international cooperation will be undertaken.

(1) Promotion of Deep-Sea Survey and Research by Deep-Sea Submarine Survey Ship, Etc.

The development of a 6,000m-class submarine survey ship indispensable for surveying submarine mineral resources such as mangenese nodules, studying the submarine topography in connection with earthquake prediction and the deep-sea ecosystem of deep-sea microorganisms, etc., and construction of a support mother ship will continue to be promoted. At the same time, the basic design of a 10,000m-class unmanned surveyor to act as a rescue ship will be undertaken.

Also, deep-sea survey research activities will be carried out by the 2,000m-class submarine survey ship "Shinkai 2000," the support mother ship "Natsushima" and the unmanned surveyor "Dolphin 3K."

(2) Promotion of Research and Development of Diving Technology

With regard to diving technology, which is a basic technology for ocean development, the submarine work experiment ship "Kaiyo" will be used to promote actual sea area experiments at a target sea depth of 300 meters.

(3) Promotion of Overall Utilization of Sea Area

In order to shed light on the changing ocean phenomena, Japan-China joint Kuroshiro current survey research as well as research and development of ocean remote probing technology will be promoted. At the same time, research and development of ocean observation technology such as an ocean laser, ocean automatic observation, etc., will be promoted.

Also, implementation of regional joint research and development carried out cooperatively by state and local public bodies as part of the sea water project aimed at development of overall sea area utilization technology will be promoted.

4. Promotion of Research and Development on Substance/Material-Oriented Science and Technology

Substance/material-oriented science and technology is important as a basic technology of all kinds of science and technology, and it will be actively promoted.

(1) Promotion of Research on Superconducting Materials

With regard to the new oxide superconducting materials recently discovered, research and development is very important because if it can be made practical, the social and economic impact will be great. For this purpose, an advanced large-scale research facility will be built up on the basis of such key organs as the Metal Materials Technology Research Institute, the Inorganic Materials Research Institute, the Institute of Physical and Chemical Research, the Japan Atomic Energy Research Institute, etc. Through joint research, the strength of industry, academia and the government will be concentrated in a framework open to organizations from at home and abroad. A superconducting materials research multicore project to advance basic and fundamental research and development will be promoted. Also, research on metals-oriented superconducting materials will continue to be promoted.

(2) Promotion of Basic/Leading Research and Development, Etc.

At the Metal Materials Technology Research Institute and the Inorganic Materials Research Institute, in order to promote basic and leading research and development, the buildup of a research and development framework will be promoted. At the same time, the solution of basic problems leading to the creation of materials having new functions (frontier materials) that form the basis of fields such as information science, etc., in the new era will be promoted as part of an international frontier research system. Also, in order to create the seeds of innovative technology in the materials field, a creative science and technology promotion system will be utilized, along with promotion of coordinating science and technology spending. Research on basic technology to develop functional gradient materials will be actively promoted.

5. Promotion of Life Science

With regard to life science, which contributes broadly to enhancement of man's well being, special priority will be placed on basic research to find the explanation of sophisticated functions of organisms. Leading and basic research and development of life science will be strongly promoted.

(1) Promotion of Leading/Basic Research and Development of Life Science Centering on Human Science Technology

At the Institute of Physical and Chemical Research, in order to obtain important heredity information for use in broad fields of life science such as cancer research, hereditary disease research, immunity research and senility research, analytical research on human chromosome genes will be promoted, as well as research on nervous system and immunity genes. Also, in order to contribute to the fight against AIDS, research and analysis of the HIV retrovirus gene structure will be undertaken, while construction of a gene recombination research building will be promoted. Furthermore, research on explaining the thinking function will be undertaken anew as part of an international frontier research system.

The creative science and technology promotion system will be utilized to promote research on plant information substances, etc. In addition, prom tion of coordinating science and technology spending will be utilized to promote leading and basic research and development, such as the development of basic technology to explain brain function and the development of basic technology to explain the immune response system.

(2) Promotion of Cancer-Related Research

The development of common basic technology necessary for research on cancer using recombinant DNA technology through promoting the coordination of science and technology spending at the Institute of Physical and Chemical Research and the development of an anticancer agent based on the commission development system by the Research Development Corporation of Japan will be promoted, while research on cancer diagnosis and treatment by radiation and construction of heavy particle beam cancer treatment equipment will continue to be promoted at the Radiation Medical Science General Research Institute.

(3) Promotion of Research and Development of Science and Technology Responding to Long-Life Society Including Senility Research

Research on understanding the senility syndrome will continue to be promoted at the International Frontier Research System, and construction of a senility experiment building will be promoted.

6. Promotion of Research and Development of Earth Science and Technology

In order to contribute to the explanation of various phenomena worldwide such as abnormal weather, research, development and utilization of earth science and technology such as research and development of remote-sensing technology and research and development to prevent natural disasters using earth observation satellites will be promoted.

(1) Promotion of Research and Development of Earth Observation Technology

As independent earth observation measures of our country, ocean observation satellite No 1b, geostationary meteorological satellites No 4 and No 5, earth resource satellite No 1 and earth observation platform technology satellite will be developed. Also, research, development and utilization of remote-sensing technology for earth observation will be promoted by such means as the data receiving and analysis evaluation carried out through ocean observation satellite No 1, our country's first earth observation satellite, and the earth observation satellite (Landsat) of the United States. Furthermore, research and development of the ocean observation technology necessary to understand and explain the broad area of changing ocean phenomena will be promoted, as will earth science and technology related research such as Japan-China Kuroshio joint survey research and Japan-France joint rift survey using Science and Technology Promotion and Coordination Outlays.

(2) Promotion of Research and Development of Disaster Prevention Science and Technology

With regard to earthquake prediction, overall promotion of observation and research at the agencies concerned will be aimed at through the Earthquake Prediction Headquarters. At the National Disaster Prevention Science and Technology Center, the buildup of a research and development structure will be promoted in order to continue earthquake prediction research in the Kanto and Tokai areas, research on earthquake disasters and snow damage measures, research on volcanic dis-ster prevention, and research on weather disaster measures. Also, promotion of coordinating science and technology spending will be used to promote research on prediction of inland earthquakes.

7. Promotion of Other Important Overall Research, Etc.

(1) Promotion of Research and Development of Aeronautical Technology

At the Aerospace Technology Research Institute, a research and development framework will be built up in order to promote research on ultra supersonic aircraft component technology as a part of the research and development of innovative aerospace transport component technology. At the same time, flight testing of the "Asuka" fan-jet STOL (short takeoff and landing) aircraft will be promoted in order to continue proving various kinds of new technologies. Also, the buildup of large-scale research and development, including the remodeling of the transonic wind tunnel that forms the base for such research and development, will be promoted.

(2) Promotion of Basic Research on Laser Science and Technology, Etc.

At the Institute of Physical and Chemical Research, basic research in such fields as the laser and on optical synthesis will be promoted.

(3) Promotion of Comprehensive Resource Utilization Method

From the long-term, comprehensive standpoint, a survey aimed at the setting up of a comprehensive resource utilization method will be promoted.

(4) Promotion of Science and Technology Publicity and Enlightenment Activities

In view of the importance of gaining the understanding and cooperation of the general public nationwide in promoting science and technology, overall publicity and enlightenment activities such as the preparation and distribution of a publicity journal, the making of movies, TV and radio broadcasts and the holding of lectures and meetings will be undertaken.

Fiscal 1988: Science and Technology Agency Overall Budget Request List
(unit: million yen; (F): future obligation)

Classification	Previous Fiscal Year Initial Budget	Fiscal 1988 Approximate Request Amount	Comparison Up △: Down	Ratio To Previous Fiscal Year
1. General account	(F) 139,353 333,674	(F) 169,228 344,187	(F) 29,875 10,513	103.2%
2. Industrial investment special account	4,300	5,600	1,300	130.2%
3. Electric power development promotion measures special account	(F) 82,060 94,552	(F) 82,011 94,752	(F)△ 49 200	100.2%
(1) Electric power source location account	12,596	15,182	2,586	120.5%
(2) Electric power source diversification account	(F) 82,060 81,956	(F) 82,011 79,570	(F)△ 49 △ 2,386	97.1%
Science and Technology Agency: Total	(F) 221,413 432,526	(F) 251,239 444,539	(F) 29,826 12,013	102.8%

Major Contents

Item	Previous Fiscal Year Initial Budget A	Fiscal 1988 Approximate Request Amount B	Comparison Up Δ : Down B - A	Remarks
1. Overall Development of Science and Technology Administration including	8,483	9,572	1,089	112.8%
(1) Establishment of Science and Technology Policy Research Institute	0	290	290	Established on 1 July 1988; Resource Survey Institute abolished
(2) Increase in Science and Technology Coordinated Spending Promotion	8,400	9,200	800	International floating basic research promotion system established
2. Buildup and Strengthening of Creative and Basic Research	(F) 491 4,843	5,795	(F)Δ 491 952	119.7% (including amount reappropriated from other item)
(1) Promotion of Human Frontier Science Program	[150]	[300]	[150]	Estimated amount to be appropriated from science and technology coordinated spending promotion
(2) Expansion of International Frontier Research System	(F) 491 1,535	1,539	(F)Δ 491 4	Buildup of research in two fields: organism homeostasis and frontier materials Initiation of one new field (thinking function)

(3) Expansion of Creative Science and Technology Promotion System	3,158	3,956	798	Three new problems (quantum function structure (tentative name), picosecond chemistry (tentative name), plant information substance (tentative name))
3. Promotion of Science and Technology International Cooperation	(F) 43,736 29,719	(F) 56,105 34,447	(F) 12,369 4,728	115.9% (reappropriated from other item)
General Account	(F) 43,736 29,383	(F) 56,105 33,748	(F) 12,369 4,365	(F)55,199 •Cooperation with advanced countries 28,169
Industrial Investment Special Account	336	699	363	•Cooperation with developing countries 2,282
including Strengthening of International Exchange of Capable Men	[1,807]	[2,138]	[331]	(Reappropriated from other item) •Exchange of capable men with advanced countries 1,407 •Exchange of capable men with developing countries 402
4. Buildup of Base for Research and Development	9,439	11,495	2,056	121.8%
(1) Promotion of Regional Science and Technology	[8]	[269]	[261]	(Reappropriated from other item) Promotion of upgrading regional research and development
(2) Promotion of Large-Scale Synchrotron Radiation (SOR) Facility Project	[69]	[778]	[709]	(Reappropriated from other item) Research and development on large-scale synchrotron radiation (SOR) facility

(3) Promotion of Research Exchange Among Industry, Academia and Government	2,499	2,576	77	·Specially designated joint research by government and private sector 151 ·Participation in academies at home and abroad by government researchers 473 ·Hi-tech consortium system 209 ·Research Development Corporation of Japan (RDC) 1,598 (Total amount of RDC including creativity science and high-tech 5,763) ·Upper limit of contract for development in commission 5.4 billion yen
(4) Promotion of Communicating Science and Technology Information	6,373	7,695	1,322	Japan Science and Technology Information Center 7,688 including ·Buildup of database 5,220 ·Buildup of on-line service 3,285
General Account	2,073	2,095	22	Including
Industrial Investment Special Account	4,300	5,600	1,300	·Development of new on-line presentation system (JOIS-III) 468 ·Operation of international science and technology information network (STN) 752 ·Construction of machine translation system 394

(5) Buildup of Collection, Preservation and Presentation System for Gene Resources, Etc.	490	342	△ 148	·Cell/gene preservation work 218 ·Microorganism system preservation and presentation work 102
5. Promotion of Research and Development of Advanced/Important Science and Technology Field	(F) 221,363 412,553	(F) 251,239 420,722	(F) 29,876 8,169	102.0%
(1) Promotion of Atomic Energy Research, Development and Utilization, and Safety Measures	(F) 118,359 273,363	(F) 127,516 272,885	(F) 9,157 △ 478	99.8%
(General Account)	(F) 36,299 178,811	(F) 45,505 178,133	(F) 9,206 △ 678	99.6%
Including: A. Buildup and Strengthening of Atomic Energy Safety Measures and Nuclear Non-proliferation Response	1,982	1,996	14	·Enforcement of Atomic Reactor Control Law 141 ·Security measures, nuclear substance protection 605
B. Japan Atomic Energy Research Institute	(F) 23,129 99,462	(F) 28,127 97,980	(F) 4,998 △ 1,482	Safety research (F) 8,002 10,881 Nuclear fusion research and development (F) 3,960 23,689 including construction and operation of JT-60. (F) 3,200 17,413

				•Research and development of nuclear-powered ship 7,377 •Construction of high-temperature engineering (F)5,776 test research reactor 1,532 •Radiation hi-tech (F)5,803 research 2,149 •Research and development of large-scale synchrotron radiation (SOR) facility 198
C. Power Reactor and Nuclear Fuel Development Corporation (PNC)	(F) 5,740 64,289	(F) 9,554 62,860	(F) 3,814 △1,429	Total amount of PNC including electric power development promotion (F)91,565 measure special account 137,829 •Development of (F)8,163 power reactor 33,101 including development of fast (F)4,600 breeder reactor 16,619 •Development of reprocessing technology, 8,087 including technological development of high-level waste products treatment 3,798 •Overseas prospecting for uranium 3,000 •Development of uranium (F)1,392 enrichment technology 2,839

[D omitted as published]	(F) 3,100 7,085	(F) 7,374 8,303	(F) 4,274 1,218	·Manufacture of heavy particle cancer treatment equipment (F)7,374 2,833
E. Atomic Energy Research by Institute of Physical and Chemical Research	(F) 4,330 3,549	(F) 450 4,419	(F)△3,880 870	·Construction and operation of heavy ion accelerator (F)450 3,473 ·Technological development of laser method uranium enrichment 395 ·Research and development of large-scale synchrotron radiation (SOR) facility 401
F. Atomic Energy Testing and Research by National Test and Research Organs	1,789	1,899	110	·Package appropriation of atomic energy test research spending of government agencies
(Electric Power Development Promotion Measure Special Account)	(F) 82,060 94,552	(F) 82,011 94,752	(F) △49 200	100.2%
A. Electric Power Location Establishment Account	12,596	15,182	2,586	120.5% ·Commission expense for atomic energy power generation safety measures, etc. 6,295 ·Subsidy for electric power location promotion measures 3,857 ·Special subsidy for electric power location establishment 1,424 ·Subsidy for atomic energy power generation safety measures, etc. 3,467

B. Electric Power Diversification Account	(F) 82,060 81,956	(F) 82,011 79,570	(F) △ 49 △ 2,386	97.1%
(a) Power Reactor and Nuclear Fuel Development Corporation	(F) 82,060 77,264	(F) 82,011 74,969	(F) △ 49 △ 2,295	·Construction of "Monju" fast breeder reactor (F)60,908 ·Research and development on new-type converter reactor, experimental reactor 701 ·Development of reprocessing (F)18,501 8,917 ·Construction and operation of uranium enrichment prototype plant 2,403
(b) Other	4,692	4,601	△ 91	·Commission of atomic reactor decommissioning technology and development, etc. 1,829 ·Commission of laser-method uranium enrichment technological development 821 ·Subsidy for technological development of radioactive waste product treatment and disposal 489
(2) Promotion of Space Development and Utilization including	(F) 94,190 94,569	(F)118,735 99,599	(F) 24,545 5,030	105.3%
A. National Space Development Agency	(F) 94,035 92,648	(F)118,588 97,629	(F) 24,553 4,981	·Development of H-II rocket (F)51,553 33,717 ·Development of communications satellite No 3 2,233 ·Development of geostationary meteorological satellite No 4 (F) 100 1,566

				•Development of marine observation satellite No 1b (F) 1,967 615 •Development of broadcast satellite No 3 (F) 4,648 3,780 •Development of earth resource satellite No 1 (F) 3,858 3,662 •Development of technological test satellite VI type (F)25,651 5,108 •Development of earth observation platform technology satellite (F) 4,263 774 •Development of geostationary meteorological satellite No 5 (F) 806 332 •Research and development of experimental data relay/tracking satellite (F) 537 129 •Development of primary materials experiment system (F) 1,336 809 •Participation in space station project (F)14,319 6,876
B. Space Science and Technology-Related Research of Aerospace Technological Research Institute	(F) 155 1,387	(F) 147 1,427	(F) 8 40	•Research of liquid oxygen and liquid hydrogen rocket engine component for H-II rocket (F) 147 232
(3) Promotion of Ocean Development	(F) 7,135 7,727	9,626	(F)△ 7,135 1,899	124.6%

A. Ocean Science and Technology Center	(F) 7,135 7,516	9,414	(F)△ 7,135 1,898	·Deep-sea survey research, including: 6,504 ·Construction of 6,000m-class submarine survey ship 3,780 ·Construction of support mother ship 1,282 ·Research and development of diving operation technology, including: 1,198 ·Operation of submarine work experiment ship 994 ·Regional joint research and development 90
B. Other	211	212	1	·Survey and research on development and utilization of Kuroshiro current 114
(4) Promotion of Research and Development on Substance/ Material-Oriented Science and Technology including New Superconducting Materials	(F) 231 9,437	(F) 2,839 11,580	(F) 2,608 2,143	122.7% (including amount reappropriated from other item) (F)1,511
Research-Related Item	0	(F) 2,839 2,362	(F) 2,839 2,362	·Metal Materials Technology Research Institute including 5,400 ·Buildup of superconducting property evaluation system in very strong magnetic field (F)1,511 1,035

				•Inorganic Materials Technology Research Institute including (F)1,328 2,312
				•Buildup of electronic microscope of very high resolution and very high voltage 931 280
				•Estimated amount to be appropriated from science and technology coordinated spending promotion 2,300
				•Creative science and technology promotion system (chemical recognition, quantum function structure (tentative name), picosecond chemistry (tentative name)) 597
				•Frontier research (frontier material) 384
(5) •Promotion of Life Science including	(F) 4,080 11,908	(F) 8,462 13,124	(F) 4,382 1,216	110.2% (Reappropriated from other item) (F)1,088
•Research and Development of Human Science and Technology	(F) 440 2,016	2,118	(F) △ 440 102	•Institute of Physical and Chemical Research including 2,875
•Cancer-Related Research	(F) 3,639 5,545	(F) 7,374 6,474	(F) 3,735 929	•Frontier research (organism homeostasis, thinking function) 556
				•Research on brain, nervous system, immune system science and technology, etc. 360

				·Estimated amount to be appropriated from science and technology coordinated spending promotion 1,900
				·Estimated amount for commission development of new technology 1,543
				·Creative science and technology promotion system (plant information substance (tentative name), etc.) 1,642
				·Radiation Medical General Research (F) 7,374 Institute 4,601 including ·Research on medical utilization of heavy (F) 7,374 particle beam 2,993
(6) Promotion of Research and Development of Earth Science and Technology	(F) 14,074 18,232	(F) 10,994 18,200	(F)△3,080 △32	99.8%
A. Promotion of Research and Development of Earth Observation Technology	(F) 14.049 15,677	(F) 10,994 15,607	(F)△3,055 △70	(Reappropriated from other item) ·Development of geostationary meteorological weather satellite (F) 100 No 4 1,566 ·Development of ocean observation (F) 1,967 satellite No 1b 615 ·Development of earth resource (F) 3,858 satellite No 1 3,662

				•Development of earth observation platform technology satellite (F)4,263 774
				•Development of geostationary meteorological satellite No 5 (F) 806 332
B. Promotion of Research and Development of Disaster Prevention Technology	(F) 25 2,555	2,593	(F)△ 25 38	•National Disaster Prevention Science and Technology Center including 2,588 •Research on earthquake prediction 940 •Research on earthquake disaster measures 503 •Research on snow disaster measures 75
(7) Other Important Overall Research, Etc.	(F) 1,034 18,988	(F) 2,149 19,416	(F) 1,115 428	102.3%
A. Aeronautical Technollgy-Related Research by Aerospace Technological Research Institute	(F) 494 8,880	(F) 1,061 8,856	(F) 567 △ 24	•Research and development of fan-jet STOL aircraft 2,426 •Research and development of innovative aerospace transport component technology (F) 753 (total including space) 750 Total amount of Aerospace Technological Research Institute including space-related research (F)1,208 10,283

B. Other	(F) 540 10,108	(F) 1,088 10,560	(F) 548 452	• Institute of Physical and Chemical Research (IPCR) including (F)1,088 10,278 • Research on laser science and technology 216 (Total amount of IPCR including atomic energy research and frontier research (F)1,538 16,236) • Promotion of method of resource utilization 78 • Promotion of science and technology publicity and enlightenment activities 129

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23 May 1988